KANSAS CITY SOUTHERN RAILWAY
TWENTY-FIRST CENTURY PLANNING

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Rail yards serve as major nodes that facilitate delivery of cargo to the consignee. The level of operational efficiency maintained within rail yards determines whether customers receive cargo late. Various external and internal factors can impede the operational efficiency of rail yards. The future growth of rail industry depends on how well it manages a potentially serious problem inherent to all railroads--rail congestion.

This study reviews the processes that occur within the Knoche rail yard, which is located in Kansas City, Kansas. In an effort to improve the operational efficiency of the Knoche rail yard or to minimize congestion, the study will reveal the results of analyzing varying strategies to improve the operational efficiency of a single event, the rip track facility, within the Knoche rail yard.

This study reveals that the operational efficiency of the Knoche rail yard may be enhanced if the following occur: (1) increase the rip track facility queue population from fifteen to twenty-two and (2) spot bad order cars directly onto the two tracks leading into the rip track facility. Finally, the amount of double handling by switch engines daily may be decreased by as much as 96% within the rail yard.

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

KANSAS CITY SOUTHERN RAILWAY: TWENTY-FIRST CENTURY PLANNING by MAJ Robert A. Powell, USA, 78 pages.

Rail yards serve as major nodes that facilitate delivery of cargo to the consignee. The level of operational efficiency maintained within rail yards determines whether customers receive cargo in a timely manner. Various external and internal factors can impede the operational efficiency of rail yards. The future growth of the rail industry depends on how well it manages a potentially serious problem inherent to railroads--rail congestion.

This study reviews the processes that occur within the Knoche rail yard located in Kansas City, Kansas, and also examines several strategies to improve the operational efficiency of the yard's rip track facility.

This study revealed that the operational efficiency of the rip track facility may be enhanced if the following occur: (1) increase the queue population from fifteen to twenty-two and (2) spot bad order cars directly to the two tracks leading into the rip track facility. Finally, the amount of double handling by switch engines daily may be decreased by as much as 96 percent within the rail yard.

ACKNOWLEDGMENTS

As with all things, there is a beginning and there is an end. This journey could not have been possible without the help and encouragement of many.

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CHAPTER 1

INTRODUCTION

Background

Kansas City Southern Railway (KCS) is a Class I railroad providing efficient, reliable rail service throughout the central and southeastern United States. This railroad makes connections to and from major North American gateways as shown in figure 1. It is the nation's second largest rail company and transports a diverse mix of general commodities.[1] KCS is the core business subsidiary of the Kansas City Southern Industries, Incorporated (KCSI), a publicly held transportation company headquartered in Kansas City, Missouri. The KCS business center, comprised of both the KCS management and marketing division, is located in Kansas City, Missouri. The operations center is located in Shreveport, Louisiana, and provides oversight of rail operations and monitors all rail movement within the KCS system.

Railroad transportation is very inexpensive, but not the most reliable. Although most customers can handle long delivery times, they expect to receive cargo on time. Primary customers, such as automobile manufacturers, rely on on-time service because of low inventory at manufacturing plants.[2] The challenge, for any railroad company, is to maintain a level of quality customer satisfaction. This equates to on-time delivery of cargo to the consignee, which may be prevented if congestion exists within rail yards.

Along the KCS rail line, rail yards serve as major nodes that facilitate delivery of cargo to the consignee. These rail yards are key to providing on-time delivery to KCS customers. Within rail yards, rail cars pass through several phases. While passing

Figure 1. Kansas City Southern Railway System

through these phases, rail cars may encounter congestion. This, in turn, could result in late delivery of cargo to the consignee. The primary objective of this research project is to enhance operational efficiency by identifying actions to reduce throughput time of rail cars passing through the Knoche rail yard's rip track facility.

Research Question

In order to achieve the primary objective of this project, the following research question was posed: What actions can be implemented to reduce throughput time of rail cars passing through the rip track facility, a single event within the Knoche rail yard?

Subordinate Questions

Four supporting questions are addressed to assist in the analysis of the research question. They are:

1. What are current rail yard procedures?

2. What are the processes that occur within the Knoche rail yard?

3. What is the process of a bad order car?

4. What are the factors during the bad order process that may cause congestion?

Limitation

The gathering of sufficient data to answer the primary research question was limited since KCSI only collects data on car arrivals and departures in and out of the rail yard.

Due to time constraints, the researcher was unable to spend the required amount of time at the Knoche rail yard to collect sufficient data to perform the analysis. Therefore, subjective data (through interviews) and partial objective data provided by KCSI were used to analyze the rip track facility.

Delimitation

Although KCSI could benefit from an analysis of the entire Knoche rail yard system, this research project does not address improving the operational efficiency of the entire system. The scope of this research project focuses on improving the operational efficiency of the rip track facility. As the operational efficiency of the rip track facility is improved, the operational efficiency of the Knoche rail yard is expected to improve proportionally. That result will not be tested in this research.

Significance of Study

The future growth of the rail industry depends on how well it manages a potentially serious problem inherent to railroads--rail congestion.[3] Rail yard congestion contributes to inefficient and unreliable rail service, poor quality customer service, and lower revenue, which can cause problems in achieving goals.

KCS has short-term as well as long-term goals. KCS's short-term goal is to move cargo out of the Knoche rail yard within twenty-four hours upon arrival. This goal is difficult to sustain for several reasons. Mark Davidson, KCS Director of Strategic Studies, cites several factors: rail yard capacity, a bad order, jeopardy cars, and unpredictable quantity of arrivals and arrival times.[4]

KCS's long-term goal is to provide an outstanding transportation value to all customers conducting business with KCSI. Shippers or customers expect on-time scheduled service, consistent and efficient operations, and competitive pricing to meet their specific transportation needs. The long-term challenge is to minimize congestion to meet customer demand and satisfaction.

Customer satisfaction can be defined in numerous ways, but it is almost always defined as a quality product coupled with quality service. An excellent customer satisfaction program is the basis for any profit-generating company's success. Furthermore, a well-maintained and refined customer satisfaction program allows a company to keep pace with or outpace competitors. As KCS moves into the twenty-first century, there will naturally be a higher demand for excellent quality service.

Prior studies have not shown what practical measures can be taken to reduce the impact of congestion within rail yards. Additionally, KCSI has no operations research

cell or division to conduct an operational analysis of rail yard operations to determine strategies to minimize congestion within their rail yards. Lastly, KCSI has no standard operating procedure that governs rail yard management.[5] An analysis of the rip track facility will pave the path for future analysis of the entire Knoche rail yard system.

Knoche Rail Yard System

The Knoche rail yard, located in Kansas City, Missouri, is one of many rail yards operated by KCS. The Knoche rail yard is a vital point within the KCS network. From the Knoche rail yard, services are provided throughout the central and southeastern United States with connections to and from major North American gateways. The throughput time of cars through the Knoche rail yard determines the level of operational efficiency and the quality of service provided to the consignee.

The Knoche rail yard is divided into two operations: a receiving yard and a new yard (see figure 2). The receiving yard is the reception station for all rail cars entering the rail yard while the new yard is the location from which rail cars depart to their respective destinations. Each yard consist of one or more phases. Phases one and two occur in the receiving yard, while phases three through six occur in the new yard.

Phase one begins as rail cars enter the receiving yard from either an interchange partner or from a local industry. An interchange partner consists of a number of rail companies that utilize one another's rail line or tracks to deliver cargo to customers. KCS shares this relationship with Burlington Northern Santa Fe, Union Pacific, Illinois Missouri Rail Link, Gateway, and Norfolk Southern. Rail car inspection is the second phase. This is the first of two inspections that occur within the system. During each inspection, cars are checked for safety and maintenance in accordance with guidelines

established by the Association of American Railroads (AAR) and Federal Railroad Authority (FRA). All cars except intermodal rail cars receive both inspections. Intermodal cars are not inspected for safety or maintenance at the intermodal facility. Intermodal cars are inspected only to ensure that they are loaded properly. They have their only inspection in the new yard.[6] The safety and maintenance inspections yield one of three results. A rail car passes inspection, requires on-the-spot maintenance, or requires entry into the rip track facility to undergo extensive repair. The AAR and FRA determine what has to be repaired in a repair facility.[7] The term bad order is used for all cars requiring any type of repair. From this point on, the term *bad order* is used for cars that require entry into the rip track facility.

Upon identification, bad order cars are switched to a designated track called the rip track to await entry into the rip track facility (maintenance building) for repair. A rail car that passes inspection is immediately processed to the third phase. Rail cars identified as needing repairs are processed to the third phase (switching or classification) when maintenance is completed.

The switching or classifying operation initiates phase three, which begins in the new yard. Rail cars enter the new yard from the receiving yard and the intermodal facility. Rail cars are switched or classified according to track assignment. If a designated track is full, rail cars are placed based on space availability.

After phase three, rail cars are grouped or blocked according to destination (phase four). This operation produces a train that is ready for phase five (final inspection). After the train clears the final inspection, its departure depends upon the availability of locomotive power. As locomotive power becomes available, trains depart to a local

industry, the Illinois Missouri Rail Link or Gateway Western Railway (for an outbound delivery), or to the consignee by way of the KCS rail line. The Gateway Western Railway is a subsidiary of KCSI and works with KCS to deliver cargo to the consignee.[8]

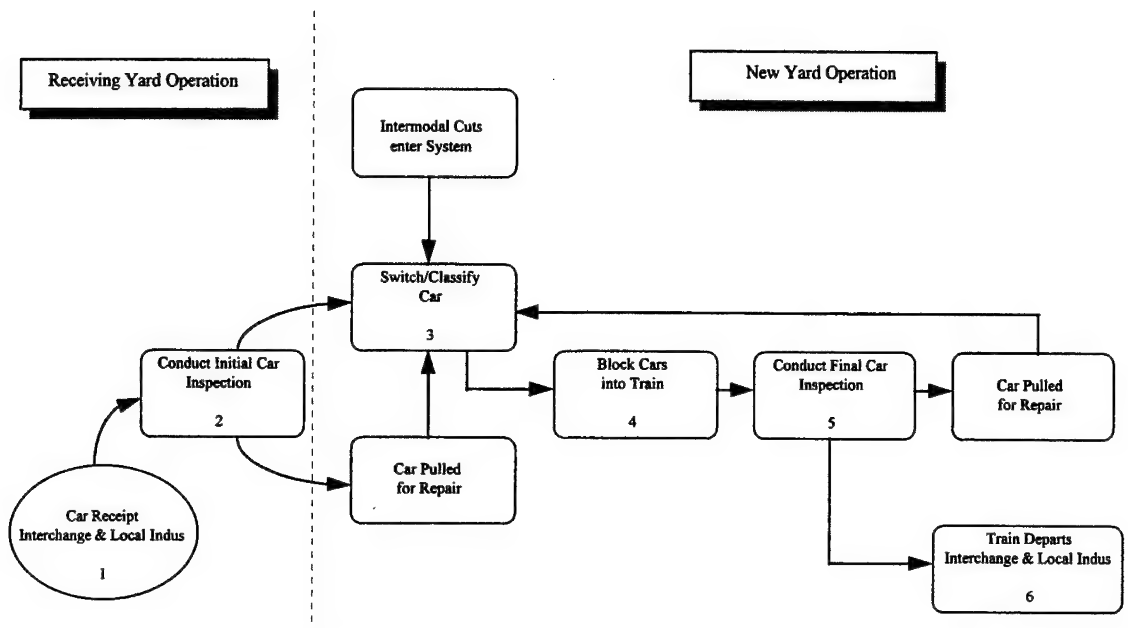

Figure 2. Knoche Rail Yard Operations

The sequence of phases presented above will assist the reader in understanding the operations of the Knoche rail yard as this research project continues.

Chapter 1 of this research project presented an introduction to the research question, subordinate questions, the limitation and delimitation of this research project, its significance, and an introduction to the Knoche rail yard system. Chapter 2 summarizes and evaluates existing literature on rail yard congestion. Chapter 3 outlines the specific operations research methods and techniques applied to solve the problem. Chapter 4 presents, explains, analyzes, and interprets the evidence produced by the

research methodology. Chapter 5 states the findings that emerge from the interpretation of the research evidence.

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[1]Kansas City Southern Industries, Inc. Brochure. (Kansas City, Missouri).

[2]Mike Wood, Superintendent, Kansas City Southern Railway, Kansas City, Missouri, interview by author, Knoche Rail Yard, Kansas City, Kansas, 9 October 1998.

[3]Robert A. Gantt, "A Study of Rail Congestion in the Kansas City Southern Railway System" (MMAS thesis., United States Army Command and General Staff College, Fort Leavenworth, Kansas, 1998), 1.

[4]Mark Davidson, Chief, Strategic Plans Division, Kansas City Southern Railway, Kansas City, Missouri, interview by author, KCS Headquarters, Kansas City, Missouri, 1 September 1998.

[5]Ibid.

[6]Dennis Lincoln, Car Foreman, Kansas City Southern Railway, Kansas City, Missouri, interview by author, Knoche Rail Yard, Kansas City, Kansas, 2 April 1999.

[7]Dennis Lincoln, Car Foreman, Kansas City Southern Railway, Kansas City, Missouri, interview by author, Knoche Rail Yard, Kansas City, Kansas, 29 December 1998.

[8]Bob Lape, Conductor, Kansas City Southern Railway, Kansas City, Missouri, interview by author, Knoche Rail Yard, Kansas City, Kansas, 12 October 1998.

CHAPTER 2

LITERATURE REVIEW

> To be able to improve terminal performance, we must be able to measure current performance. To know if policies implemented in a particular terminal are, in fact, leading to improvements in operations, it is essential that an organized "before and after" experimental approach be taken. Effective data systems for terminal control are a precondition to such an effort.[1]

The purpose of this literature review is to present a summary of pertinent research related to throughput time of rail cars. This review is divided into four sections. The first section briefly explains the recent research on car utilization and freight service reliability. The second section reviews rail yard design methods. Section three discusses current methods for optimizing rail yard operations. The last section reflects how management views terminal performance measurement systems as a means of enhancing operational efficiency in the rail industry.

Car Utilization and Freight Service

Recent studies on car utilization and freight service reliability concluded that railroad yards can adversely affect service reliability and car utilization. In 1990, the Association of American Railroads reported these findings:

> (i) For boxcar traffic less than 80% of the cars arrived at their final destination within a two day window; and that for one railroad terminal delays accounted for 20.2% of all the boxcars that failed to meet the agreed customer delivery date (see figure 3).
>
> (ii) On average, a rail car will spend 12.4 days of its 18.2 day car-cycle waiting in various downstream rail yards.[2]

Literature regarding car utilization and freight service reliability was sparse. However, the literature on designing rail yards was not as sparse.

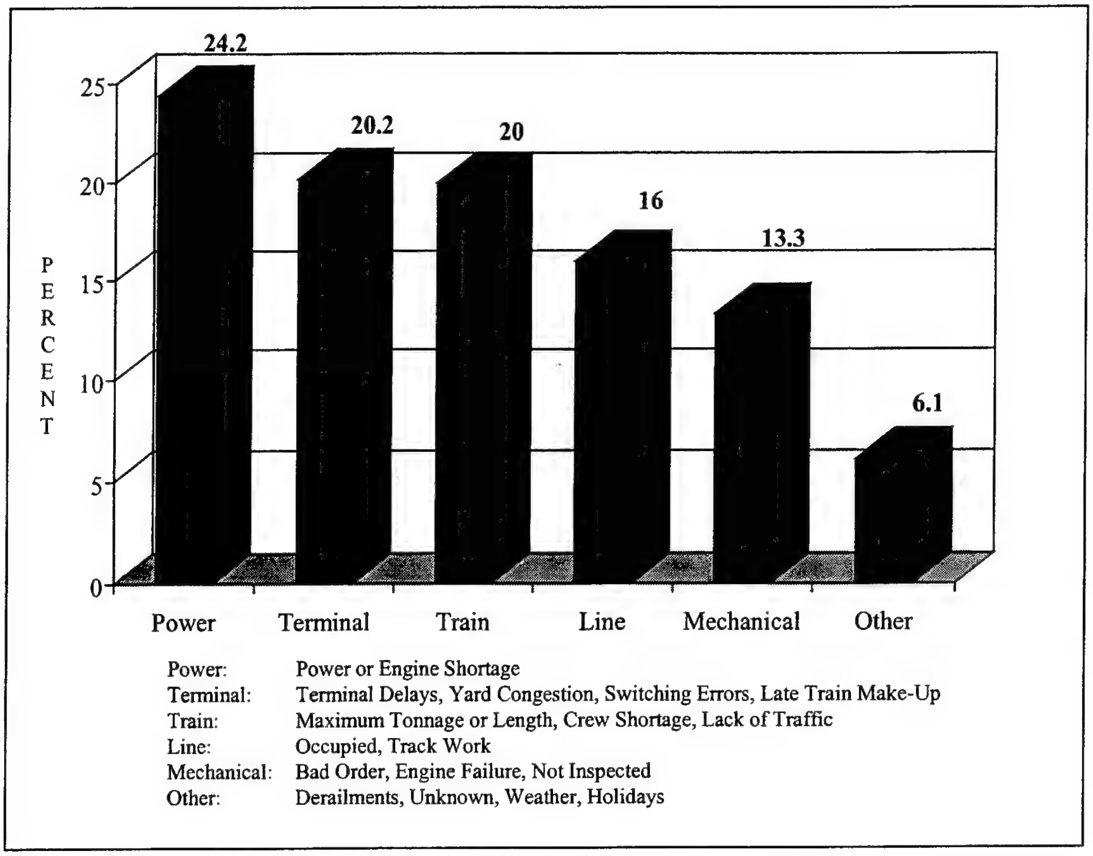

Figure 3. Causes of Shipment Delay

Rail Yard Design

In 1975, R. L. Hines Associates conducted a yard classification-planning project for the United States Railway Association. This work was the culmination of a statistical analysis of the upgrade and expansion of existing facilities based on traffic flow and unused real estate that was either part of or contiguous to the rail yard. The study analyzed fourteen specific yard operations in the proposed Conrail system. The focus of the study was on the maximum throughput of rail cars for

each of several terminals and yards premised upon one or two factors: "reasonable" upgrade and expansion of existing facilities. The ultimate determinants of the degree to which yards should be rehabilitated were the volumes and scheduling of volumes destined for classification under a coordinated system plan.[3]

Two approaches were taken in determining how best to accomplish the rehabilitation work required: a conservative approach and a radical approach.

1. The more conservative approach was used where trackage could be rehabilitated.

2. A radical approach was used where existing trackage was considered to be of no remaining value.

In some of the yard studies, a portion of the trackage was judged to require rehabilitation by the more conservative approach and other portions by the radical approach. In other yards, only one of the two approaches was indicated. The condition encountered was the determinant in each case.[4] The results of the study established the maximum throughput of rail cars for the Conrail system.

A secondary approach to analyzing the upgrade and expansion of existing facilities has been attempted by Stanford Research Institute International (SRI). SRI developed a computer simulation model called "CAPACITY" that also analyzes the design of a new yard or the rehabilitation of an existing yard. "CAPACITY" is a deterministic computer simulation model that traces the building and departure of trains, blocks, and cars in the various portions of the rail yard. It does this by tracing the movement of these trains, blocks, and cars throughout the yard.[5] The model reports the

number and lengths of tracks that are required as part of the output. The model was designed to run from *planning-level data.* Thereby, it builds the blocks for the departing trains and creates receiving, classification and departure tracks as the traffic demand requires. Its application to existing yards results in whether current or proposed design and resources are adequate based on car demand.

This simulation model was applied to two studies. In the first study, SRI used "CAPACITY" in a redesign study of the Boston and Maine's East Deerfield Yard, the most heavily utilized freight car classification facility in New England.[6] During the execution of the model, sensitivity analysis involved the testing of approximately fourteen alternatives. The purpose of the analysis was to estimate the level of traffic volume that could be handled at the East Deerfield yard under the proposed design and operating conditions. In the East Deerfield yard design, only one trial design was evaluated. However, four different traffic levels were tested to determine the level of traffic to be handled by the yard. The "CAPACITY" runs indicated that the new plan would significantly improve the yard operations, up to the point of maximum capacity. Additional conclusions include the following:

(i) Adequate physical capacity at all times is a necessity.

(ii) Cars in classification tracks can be pulled to the receiving/departure yard, but from the receiving/departure yard there is no place to go.

(iii) As receiving/departure tracks become full, power availability, unexpected traffic levels, and tracks out of service become an increasing concern.

(iv) After physical space, engines and crews proved to be the most limiting factor of the proposed yard's capacity.[7]

Overall, it was shown that the yard should handle its day-to-day traffic efficiently. The above operating characteristics are also unique to the Knoche rail yard operations, but somewhat dissimilar to the operating characteristics of a second case study.

A second case study involved the Potomac Yard of the Richmond, Fredricksburg, and Potomac Railroad, in which the CAPACITY model was used. The focus of the study was an alternative (combined northbound-southbound operations) to accommodate more intense use of the facilities. The Potomac Yard is a freight terminal, handling north-south traffic for six tenant railroads. Facilities include northbound and southbound receiving and classification yards, an engine storage yard, a piggyback yard, and repair facilities. The holding capacity is 4,500 cars, with fifty-four northbound and thirty-nine southbound classification tracks.[8] Dissimilarity exists between the Potomac and Knoche yards. The Potomac Yard is a hump yard, and the Knoche Yard is a flat yard. This factor would not limit the application of the CAPACITY model to flat yards since humping occurs automatically and switching occurs manually. Both actions would achieve similar results.

This case study sought to: (1) conduct a traffic capacity (throughput) analysis of Potomac Yard; (2) determine the functional requirements of the yard computer systems; (3) develop, analyze, and recommend alternative hardware configurations for the yard computer systems; (4) develop the functional specifications of the yard computer systems; and (5) develop implementation planning. The operation of the yard was described by the time required to perform six major functions: receive inbound trains, inspect and bleed cars, switch cars to classification tracks, makeup outbound trains,

inspect and charge outbound trains, and depart outbound trains. The model tracked the use of yard resources (engines and crews) and the expected track occupancy. The analysis indicated that, with some modifications, combining northbound and southbound operations appeared to be feasible.[9] The bias of the yard design methods is the emphasis on yard design rather than on yard operations. For example, the model creates receiving, classification, and departure tracks, as the demand requires.

Optimizing Rail Yard Operations

Donald H. Timian, in his master's thesis, analyzed three different methods designed to optimize freight rail yards. These methods will be individually discussed later in this section. In general, he noted that rail cars arrive at rail yards in one of two ways: (1) they can arrive at a rail yard as part of an inbound train; or (2) they can be delivered from a shipper's facility by a local freight train or an industry switch crew, in which crews make regular rounds of the local industries that surround a given rail yard spotting empty cars and pulling loaded cars.[10] An additional way not noted by Timian is from a yard's intermodal facility. Once cars enter the rail yard, they are inspected, sorted, and assembled with other cars to await the departure of an outbound train.

Sorted cars are placed on classification tracks to await the departure of an outbound train. Timian found that four multistage sorting strategies are used to sort inbound cars:

(1) sort-by-train, (2) sort-by-block, (3) triangular, and (4) geometric.[11]

The sort-by-train strategy operates according to a specific routine. All inbound cars are sorted onto classification tracks according to their outbound train. Next, cars belonging to a given outbound train are re-sorted according to their block or final destination,

connected together, and assembled for departure. Outbound trains then depart sequentially or as desired. The Knoche rail yard simulates the sort-by-train strategy.

Timian analyzed three different models designed to optimize freight rail yards. They are: Shi's Hump Sequencing System, Kraft's Mixed-Integer Optimization Model, and Ferguson's Switching Process Model. Shi's Hump Sequencing System and Ferguson's Switching Process Models were designed to optimize terminal operations (hump sequencing); Kraft's Mixed-Integer Optimization Model was designed to optimize both terminal operations and blocking plans.

Using the Hump Sequencing System, Shi attempted to minimize the average length of time (or cost) that a car spends in a rail yard. In developing the Hump Sequencing System, Shi considered the capacities of the receiving, classification, and departure tracks; and the time it took to block, assemble and inspect an outbound train. Shi also allowed outbound trains to be built to max-min car requirements rather than time requirements. In other words, outbound trains were built dependent upon whether additional cars would be added along the route. He used dynamic programming to compare all possible inbound train humping sequences to find the best or optimum hump sequencing train permutations. Using this approach, Shi noticed that increasing the number of candidate trains available to hump entailed more computer memory and computing time. Therefore, he developed a heuristic, designed to reduce the number of candidate trains available for humping.[12] Unlike Shi, Ferguson made use of a mathematical model to analyze switching processes.

Ferguson viewed the humping or switching at a rail yard as a general job-shop problem, whereby the jobs are the assembly of N outbound trains, and the machines (M_1 and M_2) are respectively the hump locomotive and the make-up or pull-back engine. He typified his operation as a two-machine flow shop problem (see figure 4).[13]

n/2/F/f(L)	
n - # of inbound trains	F – Flow Shop
2 - # of machines	F(L) – Minimize Maximum Lateness

Figure 4. Two-Machine Flow Shop Problem

Ferguson's model is not applicable to typical rail yards, in that it does not account for random switching among tracks. Instead, the variables are assumed to be deterministic. For example, Ferguson assumes in the model that "an entire receiving track of cars will be switched before another track is started."[14] Likewise, he assumes sufficient track space and that one hump locomotive and one pull-back engine are consistently available. A limitation of this model, when compared to overall rail yard operations is that it considers only switching operations. Another limitation lies within its objective. This model does not address congestion throughout rail yard operations.

The Mixed-Integer Linear Programming Optimization Model takes a different approach than Ferguson's model. It was designed to improve both the effectiveness and efficiency of rail yards. Kraft defines effectiveness as "sorting all cars into required blocks and trains within required time frames;" and defines efficiency as "accomplishing this at minimum cost." The key word here is "effectiveness," because the measure of a rail company's performance--as seen by the consignee--is its ability to provide reliable service.[15]

Kraft's model attempts to classify cars based on a railroad's trip plans. A railroad trip plan reflects the route a rail car will take from start to finish.[16] Like Shi's model, Kraft's model requires the capacities of the receiving, classification, and departure tracks as well as the amount of time it takes to block, assemble, and inspect an outbound train. In addition, data as to how many classified and unclassified cars were currently on hand as well as the receiving or classification tracks these cars occupied, were input via a link with the yard's own inventory control system.[17] Kraft's model had two degrees of freedom: "hump sequence" and "classification track to block assignments." The "classification track to block assignments" had this brief description:

> Throughout the time period covered, assignment as to which blocks are sorted onto which classification tracks can be fixed or variable. If allowed to vary, the model will use a sort-by-train strategy to optimize the number of classifications--and therefore the number of connections made--while holding operating costs under control.[18]

Kraft's methodology included use of an objective function to minimize the total number of times each car is rehandled, the departure tracks used and the number of connections missed. Kraft concluded that his model must be able to handle sixty tracks, ninety

blocks, and twenty-five trains simultaneously to be of commercial use. This would entail excessive execution time and memory requirements. Due to the impracticality of the exercise, Kraft suggested "that a heuristic approach . . . or a non-exact technique . . . may prove more successful" in solving the track to block assignment problem.[19]

Due to the nature of its operation, the rip track facility does not require as expansive a model. But the goal of Kraft's model is similar to KCS' goal--departing trains within required time frames to facilitate delivery of cargo to the consignee in a timely manner. Both Kraft's and Shi's models reveal that a mathematical model for managing rail road yard operations must include considerations, such as track capacities and time to conduct various events within a rail yard. The underlying theme of Timian's research was improving the decision support systems at rail yards by optimizing both terminal operations and blocking plans. It was his opinion that work similar to Kraft's Mixed-Integer Optimization Model was the direction in which future research should proceed.[20]

Both Shi's and Kraft's models lend themselves to the implication that rail yards are best analyzed using operations research systems analysis techniques.

One last study discussed in this section (Optimizing Rail Yard Operations), relates to the human dimension--a factor that potentially contributes to congestion. The human dimension, with all its vagaries, is difficult to simulate using any Operations Research discipline.[21] SRI conducted a study that reviewed this factor.[22] SRI focused on the human factors involved in operating the Grand Trunk Western's Railroad. In this study, *key* decision makers and *key* decision variables were identified. The train master, yard

master, dispatcher, and yard conductor were identified as key decision makers and interviewed on performing their function. The project achieved significant advances in developing new tactical operations planning procedures. The results of the research were as follows: (1) dispatchers and yard masters planned their shift operations inefficiently. These conditions produced less efficient local and system wide operations resulting in non-optimal labor productivity, excessive car transit times, inefficient car utilization, and trip unreliability, and (2) new tactical operations planning procedures for both dispatching and yard operations were recommended.

Overall, the research efforts on optimizing rail yard operations indicated that a yard can be run better with accurate, up-to-date and predictive information. The impact of the "human dimension" on Knoche rail yard operations will not be reviewed in this study; however, it may be worth exploring when conducting further research of KCS operations. This particular review reveals the significance of a railroad company operating in accordance with tactical operations planning procedures.

Management Views on Terminal Performance Measurement Systems

In 1975, the Department of Transportation (DOT) sponsored a two-day seminar attended by a number of railroad companies and transportation officials. This focused on "what progress had been made in the implementation of terminal measurement systems."[23] It aimed at improving the speed, reliability, and efficiency of car movements within a terminal to produce a more salable transportation product to attract new business

and provide greater job security. Terminal performance measurement systems were used to:

(1) Evaluate performance and trigger the planning process to develop changes that will produce improved performance

(2) Evaluate experimental changes in operations to determine the actual improvement in performance

(3) Monitor operations to provide data that results in corrective action to prevent a deterioration in performance

(4) Assess the performance of managers responsible for the operations.[24]

The seminar attendees focused on six terminal car movement measurement systems. They were: Burlington Northern, Southern Pacific, Illinois Central Gulf, Southern, St. Louis-San Francisco, and the St. Louis Terminal Project. One major finding was: "the strong inter-relationships between the following areas of railroad operations prevent independent evaluations of performance: (1) terminal operations, (2) train operations, (3) power allocations, (4) crew assignments, (5) empty car dispositions, and (6) car movements."[25]

Other significant findings were grouped accordingly:

<u>Role of Measurement Systems</u>. Not only did several attendees question the value of historical data, but agreement on the role that a terminal measurement system should play in railroad management was not reached.

<u>Role of An Analyst</u>. Without an Operations Research Analyst to guide the evaluation of performance, the reports would probably go unused. Some felt that unless analytical groups of adequate size were established at the terminal level to perform the evaluation and planning functions, the information generated by measurement systems would be wasted.

<u>Management Support</u>. There was difficulty in gaining user acceptance. This factor could alone hinder successful implementation of a terminal measurement system. Finally, before management will support service

The seminar clearly showed the need for railroad companies to do business better, smarter and more efficient. Although the seminar was held more than twenty years ago, there may be some relative importance on railroad operations in the twenty-first century.

A search of the literature review revealed that rail yard analysis is common though somewhat outdated. The literature revealed a number of approaches that have been exercised (to a greater or lesser degree) to understand the dynamics of the rail industry. The literature review also uncovered information related to the design of rail yards according to traffic demand and to information on the use of mathematical techniques and processes to optimize rail yard operations. Finally, the review revealed that data are required.

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[1]Joseph M. Sussman, "The Relation of Terminal Performance to Level of Service in the Freight Industry" (speech presented at the seminar on Tactical Performance Measurement Systems, Chicago, 21-22 May 1975), Department of Transportation, Washington, D.C.

[2]Donald H. Timian, "Current Methods for Optimizing Rail Marshalling Yard Operations" (M.S. thesis, Kansas State University, 1994), 5.

[3]"United States Railway Association" (Washington, D.C.: R. L. Hines Associates, Inc., 1975), 1.

[4]Ibid., 2.

[5]Peter J. Wong et al., *"Railroad Classification Yard Technology Manual*, vol 1, *Yard Design Methods"* (Menlo Park, CA: SRI International. 1981), photocopied, 57.

[6]Masami Sakasita, Mary Ann Hackworth, and Peter J. Wong, "Railroad Classification Yard Design Methodology Study, East Deerfield Yard: A Case Study" (Menlo Park, CA: SRI International, 1980), photocopied, 1.

[7]Ibid., 36.

[8]Neal P. Savage et al., "Railroad Classification Yard Computer System Methodology, Potomac Yard: A Case Study" (Menlo Park, CA: SRI International, 1981), photocopied, 1.

[9]Ibid., 3.

[10]Donald H. Timian, "Current Methods for Optimizing Rail Marshalling Yard Operations" (M.S. thesis, Kansas State University, 1994), 1.

[11]Ibid., 4.

[12]Ibid., 14.

[13]Ibid., 27.

[14]Ibid., 28.

[15]Ibid., 21.

[16]Richard Taylor, Assistant Trainmaster, Kansas City Southern Railway, Kansas City, Missouri, interview by author, 2 April 1999, Knoche Rail Yard, Kansas City, Kansas.

[17]Donald H. Timian, "Current Methods for Optimizing Rail Marshalling Yard Operations" (M.S. thesis., Kansas State University, 1994), 22.

[18]Ibid., 22-23.

[19]Ibid., 25-26.

[20]Ibid., 35.

[21]Ibid., 38.

[22]P. J. Wong et al., *"Improved Railroad Operations Using a Railroad Automated Identification and Location System*, vol. 1, *New Procedures for Making Tactical Operations Planning Decisions"* (Menlo Park, CA: SRI International, 1977), photocopied, 48.

[23]Ibid., 1.

[24]Labor/Management Task Force on Rail Transportation, "Terminal Performance Measurement Systems" (Chicago, 21-22 May 1975, photocopied), Department of Transportation, Washington, D.C., 10.

[25]Ibid., 8.

[26]Ibid., 35-37.

CHAPTER 3

METHODOLOGY

This chapter contains the step-by-step process used to study ways to improve the operational efficiency of the rip track facility at the Knoche rail yard. This process included: (1) preliminary analysis, (2) design of experiment, (3) data collection, and (4) evaluation.

Preliminary Analysis

The review of literature resulted in the discovery of several ways to analyze congestion of rail yards from a macro approach. Although models have been designed to study the macrooperations of rail yards, not much research has been conducted on the various rail yard components that may contribute to congestion or on implementing alternatives to minimize congestion. Operations Research techniques often provide the best methods available for solving problems that involve a quantitative approach.

It was found that the Knoche rail yard resembles a classical queueing system--customers arriving for service, waiting for service if it is not immediate, and leaving the system after being serviced.[1] In the case of the Knoche yard, rail cars are treated as customers that enter the system based on space availability, wait for service and exit the system. Rail cars wait to be serviced or switched. The switch engine can be viewed as the service mechanism because it conducts rail car switching. For this type of system, it is appropriate to use an Operations Research Systems Analysis discipline--Queueing Analysis.

Design of Experiment

Queueing theory provides models (formulas) that can be used to compute the expected waiting time and the expected server utilization factor, under specified assumptions regarding the nature of the queueing process.[2] The rip track facility represents a basic queueing system--a multiple-channel, single-phase structure. Operating characteristics of operational systems describe the performance of the system in the form of such measures as expected customer waiting time and percent server utilization. However, the measures of the system's performance are actually only inputs into a broader conceptual framework within which most waiting line problems can be analyzed.[3]

The "QSIM Decision Support System" will be used to model and analyze the operational efficiency of the rip track facility. This program uses Monte Carlo simulation to analyze queueing systems. It will be used to perform the analysis of the rip track facility and to evaluate alternatives that may decrease the processing time of bad order cars flowing through the rip track facility. The objective is to improve the operational efficiency of the rip track facility. In addition, improving the efficiency rate of cars flowing through the rip track facility may have a reciprocal effect on minimizing yard congestion.

Data Collection

Data collection is key in analyzing the rip track facility. To conduct the analysis, data have to be collected on the nature of the operation. These data serves as inputs for the QSIM simulation to determine the current operational efficiency of the rip track facility. Once a basic operating state is determined, experiments are conducted using the

data to reduce the throughput time of bad order cars flowing through the rip track facility. KCSI does not possess the capability to capture required data, so data will be obtained two ways: objectively and subjectively.

KCSI tracks data of all cars undergoing repair, independently of whether they pass through the rip track facility. A portion of these data will be used to calculate arrival and service times, which will be used as inputs into QSIM. Additional data will be collected through interviews with senior railroad personnel.

Evaluation

Basic queueing theory definitions and notation are listed in figure 4. The operating characteristics commonly obtained in the analysis of waiting lines are summarized as follows:

1. ρ the fraction of the time that a server is busy
2. L the average number of customers in the system
3. L_q the average number of customers waiting for service
4. W the average time a customer is in the system
5. W_q the average time a customer will have to wait in the queue before being served

Figure 5 depicts the input and output parameters used in the analysis and evaluation of the rip track facility. The output parameters, noted above, were used to measure and evaluate the processing time of bad order cars flowing through the rip track facility.

c	Number of identical servers
λ	Average arrival rate of customers to the system
μ	Average service rate per server, that is, the average rate of service completions while the server is busy
ρ	The fraction of the time that a server is busy
n	Target number of customers in the system
p_n	The probability that the system contains n customers at time t, assuming some initial number at time 0
$p0$	The fraction of time the server is idle
L	The average number of customers in the whole system, queue and server
L_q	The average number of customers waiting for service
W	The average time a customer is in the system measured from the time of arrival to the time exiting the server
W_q	The average time a customer will have to wait in the queue before being served

Figure 5. Basic Queueing Theory Notation and Definitions

The operating statistics depicted in figure 5 will provide KCSI management with a microscopic view of the efficiency of the rip track facility--average car repair times, queue lengths and server utilization. KCSI can further use this information to answer the questions: What if? and How can I? by introducing alternatives to cause a desired outcome--the effect of reduced car repair times on on-time cargo delivery and potentially increased revenue.

Conclusion

Approximately 10 percent of cars arriving to the Knoche rail yard become bad order cars that require service in the rip track facility.[4] Since the repair facility is a potential bottleneck within the Knoche rail yard, congestion in the facility can contribute to congestion in the Knoche rail yard. Reducing the amount of time a bad order rail car spends in the rip track facility is a way of reducing congestion in the Knoche rail yard.

Although a reduction in car repair time may reduce congestion in the rip track facility, in no way does this imply that congestion would be completely eliminated within the Knoche rail yard. Nonetheless, it is a step toward improving operational efficiency within the Knoche rail yard.

The output of the QSIM simulation will provide KCSI management with a microscopic view of the efficiency of the rip track facility. It will also give them the ability to analyze the impact of a procedural change to the rip track facility operation. Finally, it is expected that a subjective analysis of the bad order car handling process will result in a more efficient way of conducting operations that will enhance the operational efficiency within the Knoche rail yard.

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[1] Donald Gross and Carl M. Harris, *Fundamentals of Queueing Theory* (New York: John Wiley & Sons, 1985), 1.

[2] Sang M. Lee, Laurence J. Moore, and Bernard W. Taylor III, *Management Science* (Boston: Allyn and Bacon, Inc., 1985), 506.

[3] Ibid., 503.

[4] Dennis Lincoln, Interview by author, 29 December 1998, Kansas City, Kansas, Knoche Rail Yard, Kansas City, Kansas.

CHAPTER 4

ANALYSIS

The purpose of this research project is to improve the operational efficiency of the rip track facility at the Knoche rail yard. This chapter will present, explain, analyze, and interpret the evidence produced to answer the primary research question as well as the subordinate questions. The primary research question is: What actions can be implemented to reduce the throughput time of rail cars flowing through the rip track facility? The subordinate questions are:

1. What are current rail yard procedures?
2. What are the processes that occur within the Knoche rail yard?
3. What is the process of a bad order car?
4. What are the factors during the bad order car process that may cause congestion?

This chapter is divided into seven parts: (1) standard operating procedures, which addresses the first subordinate question; (2) Knoche rail yard processes, which addresses the second subordinate question; (3) bad order car process, which addresses the third subordinate question; (4) factors that may cause congestion during the bad order car process, which addresses the fourth subordinate question; (5) subjective analysis of the rip track facility; (6) objective analysis, which addresses the primary research question; and (7) research difficulties.

Standard Operating Procedures

In a recent Master of Military Art and Science study, a major finding was the absence of written operating procedures and standards pertaining to Knoche rail yard operations. Robert Gantt, in determining lack of locomotive power to be the leading cause of rail congestion within the Knoche rail yard, made this finding:

> Aside from the Code of Federal Regulations CFR 49, KCSR "pocket quide," and superintendent originated memoranda, no standardized company operating procedures exist. The absence of written operating procedures and standards likely has a degrading effect on training and operations. Absence of written procedures makes it difficult to maintain consistency and continuity of operations, especially during turnover of managers and personnel. Written operating procedures aid managers and leaders in formulating objectives and goals and providing minimum guideposts on which to base performance as well as the ability to judge or measure results.[1]

Stanford Research Institute International, in conducting interviews of key decision makers (train master, yard master, dispatcher, and yard conductor) made this finding:

> Dispatchers and yard masters planned their shift operations inefficiently. These conditions produced less efficient local and system wide operations resulting in non-optimal labor productivity, excessive car transit times, inefficient car utilization, and trip unreliability.[2]

As a result of these findings, new tactical operations planning procedures for both dispatching and yard operations were recommended. To date, KCSI maintains no standard operating procedures that govern how rail yard personnel conduct rail yard operations.[3] The absence of standard operating procedures may result in inefficiency throughout the KCS rail line. This is an area that requires further study.

Knoche Rail Yard Processes

The Knoche rail yard is divided into two operations: receiving yard and a new yard (see figure 6). Phases one and two occur in the receiving yard, while phases three through six occur in the new yard.

Phase one begins as rail cars enter the receiving yard from either an interchange partner or from a local industry. Rail car inspection is the second phase. This is the first of two identical inspections that occur within the system.

During each inspection, cars are checked for safety and maintenance in accordance with guidelines established by the Association of American Railroads (AAR) and Federal Railroad Authority (FRA). All cars except intermodal rail cars receive both inspections. Prior to arriving to the new yard, intermodal rail cars are inspected at the intermodal facility to ensure they are loaded properly. The intermodal rail cars, unlike other cars, receive their only safety and maintenance inspection in the new yard.[4] The safety and maintenance inspections yield one of three results. A rail car passes inspection, requires on-the-spot maintenance, or requires entry into the rip track facility to undergo extensive repair. Other rail cars, besides those entering the rip track facility, may also require repair. The AAR and FRA determine what has to be repaired in a repair facility.[5] All other rail cars needing repair are likely to be repaired outside the rip track facility but also may undergo repair at the rip track facility. Upon identification, bad order cars are switched to a designated track called the rip track (track number seventeen), track number twenty-one, or an available switch track to await entry into the rip track facility (maintenance building) for repair. Track number twenty-one is

commonly called the *GI* track. A rail car that passes inspection is immediately processed to the third phase (switching or classification). Rail cars that have been identified as needing repair will be processed to the third phase when maintenance has been completed.

The switching or classifying operation initiates phase three, and occurs in the new yard. In the new yard, rail cars are switched or classified according to track assignment. Sixteen tracks have been designated for switching and are capable of holding from 14 to 45 rail cars. The tracks, delineated according to car destination, are capable of holding a total capacity of 505 cars. In the event that a designated track is full, rail cars are placed on other tracks on a space available basis. Intermingling routinely occurs as the population of cars entering the yard and destined for a specific point on the rail line exceeds the capacity of that respective switch track. This causes a switch engine to spend additional time acquiring the rail cars. This is due, in part, to the yard layout and design, which will be discussed later in this chapter.

After phase three, a railroad trip plan (located in Appendix C) that identifies a train route determines how cars are grouped or blocked. Four tracks are used for blocking, with each track capable of holding 35 to 40 rail cars. All rail cars bound for a specific route are blocked into a single train according to destination. Then, the train is ready for event five (final inspection). After the train clears final inspection, its departure depends upon the availability of locomotive power.

As locomotive power becomes available, trains depart to a local industry, the Illinois Missouri Rail Link or the Gateway Western Railway (for an outbound delivery),

or to the consignee by way of KCS rail line. The Illinois Missouri Rail Link is an independent rail company that shares joint ownership of the Knoche rail yard; and the Gateway Western Railway is a subsidiary of KCSI and works with KCS to deliver cargo to the consignee.[6] If cars have to be picked up at other rail yards along a route, a train will depart out of the Knoche rail yard lighter than normal.[7] Appendix D shows a detailed flow chart of the life of a rail car as it flows through the Knoche rail yard.

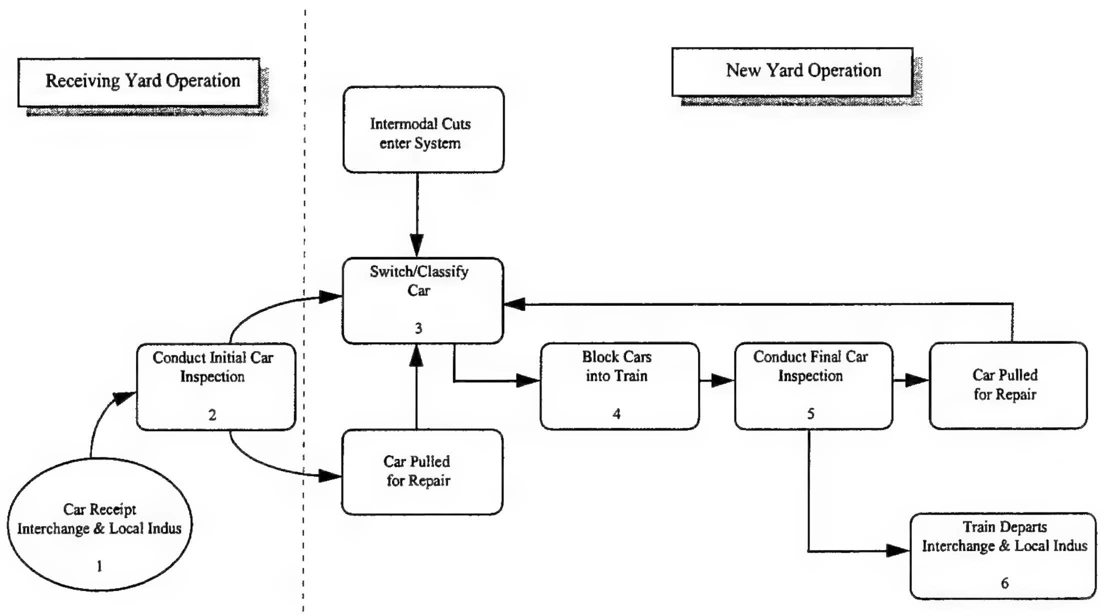

Figure 6. Knoche Rail Yard Operations

Bad Order Car Process

Approximately 10 percent of rail cars arriving at the Knoche rail yard become bad order rail cars that require service in the rip track facility.[8] This involves approximately 15 to 20 cars per day. Rail cars are identified as bad orders during the

initial and final car inspections that occur within the Knoche rail yard. Upon identification, bad order cars are spotted to the rip track or to the GI track. These are designated as staging tracks for all cars requiring repair, whether or not they need to enter the rip track facility. Although these two tracks are primarily used for bad order cars, other type cars are routinely placed on the same tracks. If there is an overflow from these tracks, other tracks are used at random.[9]

Bad order cars are spotted (in batch arrivals) daily on two tracks leading into the rip track facility, at a rate of fifteen cars per day.[10] The rip track facility covers only a portion of these two tracks; however all cars placed on these tracks, whether inside or outside of the facility, can be serviced. For example, the rip track facility can hold up to 2 to 3 cars per track depending on whether they have to be lifted. The portion of the tracks extending beyond the rip track facility can hold ten and twelve cars respectively. The queue discipline is first come-first served. The exception is when there exists a customer service commitment--an agreement between KCSI and a consignee that guarantees the delivery of cargo within prescribed time periods.[11] In this case, customer service commitment cars preempt cars already in the queue.

As cars enter the rip track facility queue, two repairmen service the cars. Upon completion of repair, bad order rail cars are classified as "okay" and pulled from the rip track facility and staged on a switch track to await departure.

Bad Order Car Process: Congestion Factors

Three factors during the bad order rail car process may contribute to congestion. They are (1) car inspection time, (2) switch engine availability, and (3) bad order customer service car commitment.

Bad order cars arrive at the Knoche rail yard at a rate of 15 to 20 cars per day.[12] This accounts for approximately 10 percent of the total inventory that enters the Knoche rail yard daily. The rate at which rail cars are inspected determines how smoothly rail cars move through the system, enter the rip track facility, and are ready for departure. If the rate at which rail cars arrive exceeds that of the inspection rate, congestion can occur within the Knoche rail yard. All rail cars experience at least one inspection.

A second factor is switch engine availability. As cars are identified as bad orders, they are spotted to tracks in the new yard to await entry onto tracks leading into the rip track facility. A switch engine is required to move bad order cars to their respective tracks, and to and from the rip track facility. A switch engine is earmarked to conduct a spot and pull to the rip track facility at least once daily. Besides this activity, a switch engine is also used to: 1) spot and pull cars, 2) transfer cars to switch tracks, 3) build trains, 4) spot and pull intermodal cars, and 5) transfer cars to other rail companies. Four switch engines are normally available to conduct operations 2) and 3) above, to include switching bad order cars in the Knoche rail yard.[13] When a switch engine is unavailable, these cars may stockpile in the receiveing yard and new yard. When this happens, congestion can occur. Devising a method to minimize the demand for a switch engine

throughout the yard can reap both a qualitative and economic benefit to KCSI management.

Due to the absence of a standard operating procedure, switch engines are allocated randomly by the yard master. Consequently, a bad order car spends 40 to 54 hours from the time it is identified as needing repair to the time it is switched onto classification tracks for departure.[14] It is not known whether some or the entire wait encountered during the bad order process is due to the unavailability of a switch engine. An analysis of this situation may prove helpful in determining the cause or causes. In any event, congestion could potentially be reduced if bad order rail cars, upon identification, were spotted or switched directly to the two tracks leading into the rip track facility.

Finally, congestion may occur when customer service commitment cars preempt rail cars already in the rip track facility queue. In this case, bad order customer service cars preempt rail cars already in the rip track facility queue. When this occurs, potential bottlenecks may occur if there exist cars that have to be pulled from the tracks leading into the rip track facility. For example, there is a lead for all switch tracks including the tracks leading into the rip track facility. If bad order rail cars have to be pulled from the tracks leading into the rip track facility, this lead may become blocked. If the lead is blocked, switching must be placed on hold until the lead is cleared or delivering a bad order customer service car to the rip track facility must be delayed. When this happens, either congestion may occur or KCSI may encounter difficulty in meeting the time requirements of a customer service agreement.

Subjective Analysis

This section provides a subjective evaluation of the bad order car handling process and how changes in the process may reduce the throughput time of cars flowing through the rip track facility.

Recent studies on car utilization and freight service reliability concluded that railroad yards can adversely affect service reliability and car utilization. In a speech delivered on Tactical Performance Measurement Systems in Chicago (1975), Joseph Sussman estimated that as much as 25 to 40 percent of the total time freight cars spend in classification yards is closely associated with deficiencies related to yard layout and design. He stated that this is roughly equivalent to a loss of 55 to 85 million car-days per year, and under-utilization of approximately 210,000 freight cars. He therefore concluded that yard design can have a substantial impact on the ability of a terminal to process cars.[15] This is true for the Knoche rail yard if problems experienced are due, in part, to an antiquated rail yard design and imperfect trackage conditions.

Because of the yard layout, movement of cars is at times hindered because the yard is not large enough to allow for a number of events to occur simultaneously. There are two types of yard layouts: (1) flat yard, and (2) hump yard. The Knoche rail yard is a flat yard operation and is limited in comparison to a hump yard. A hump yard has more tracks, which provides more space and maneuverability. It can accommodate 1500-1800 cars per day whereas a flat yard can only accommodate 200-300 cars per day. Additionally, there is normally no intermingling of cars going to different destinations on the same track. In a flat yard, due to limited space, cars are routinely mixed on a track

although they may not be folded into the same train.[16] Switch engines are more essential to a flat yard operation because of the layout of the yard.

As the population of cars increases, there will be an even higher demand for a switch engine; if some of this demand could be minimized, it could result in efficiency within the yard (i.e., getting cars to the facility sooner, thus minimizing the demand for a switch engine). Data reveal that for over a 6-month period, there were fifteen days (8 percent) where bad order arrivals exceeded the rip track facility capacity of twenty-two. This is shown in table 1. If, during this time, bad order cars were spotted directly to the rip track facility, the use of a switch engine may have been decreased by as much as 92 percent. Under the current operating procedure, a switch engine double handles bad order cars at times when there is space available on the two tracks leading into the rip track facility. If the utilization of a switch engine could be reduced by as much as 92 percent, it is assumed there would be a positive economic tradeoff for KCSI. Increasing car batch arrival to twenty-eight results in an increase of 4 percent (see table 2).

When switching occurs, a switch engine is employed for the duration of the switching event. With only a limited number of switch engines available, other jobs may be delayed when a switch engine is employed. If bad order cars could be switched initially to the rip track facility, this resource could be employed by other events in the yard when needed. This would allow bad order cars to arrive to the rip track facility sooner, and allow the switch engine to be more readily available for other jobs as needed.

Month	Bad Order Cars Repaired	Days Exceeding twenty-two cars	Total Days	Percentage
Sep	451	3	30	10
Oct	528	4	31	12.9
Nov	365	2	30	6.67
Dec	369	0	31	0
Jan	545	4	31	12.9
Feb	418	2	28	7.14
Total	2676	15	181	8.29

Table 1. Bad Order Car Data

Another factor contributing to congestion is that not all cars placed on rip track seventeen are designated to go through the rip track facility.[17] Bad order cars are also mixed on other switch tracks with other rail cars. This operating procedure causes the switch engine to incur additional time handling bad order cars. Again, if bad order cars were initially switched to the rip track facility, some of the intermingling and additional handling of cars could possibly be avoided. This encumbrance further contributes to the misuse of switch engines, and may potentially lead to more congestion within the Knoche rail yard.

In summary, the spotting of bad order cars directly to the rip track facility may reduce the time a switch engine is required switching bad order cars, and also increase the

Month	Bad Order Cars Repaired	Days Exceeding twenty-eight cars	Total Days	Percentage
Sep	451	1	30	3.33
Oct	528	2	31	6.45
Nov	365	1	30	3.33
Dec	369	0	31	0
Jan	545	4	31	12.9
Feb	418	0	28	0
Total	2676	8	181	4.42

Table 2. Bad Order Car Data

operational efficiency within the Knoche rail yard. This procedure may also decrease the amount of time a bad order car spends in the rail yard prior to entering the rip track facility. Finally, a switch engine may be more readily available for other operations within the Knoche rail yard.

Objective Analysis

An objective analysis was conducted to determine the feasibility of delivering twenty-two cars to the rip track facility daily over a period of one and two shifts. The data used to conduct this analysis were obtained through interviews and automated data obtained from KCSI. A portion of these data are in Appendix A. The automated data capture all cars experiencing repair whether or not they pass through the rip track facility.

Rick Mygatt, Mechanical Supervisor, indicated that only 85 to 90 percent of the data represent bad order cars that enter the rip track facility.[18] A 90 percent estimate is used in this analysis.

Data were input into the QSIM simulation to depict a picture of the operating characteristics of the current system. Queueing theory processes (formulas) were used to derive the following operating statistics:

1. ρ the fraction of the time that a server is busy
2. L the average number of customers in the system
3. L_q the average number of customers waiting for service
4. W the average time a customer is in the system
5. W_q the average time a customer will have to wait in the queue before being served

The server utilization factor was used to determine if it was feasible to deliver twenty-two cars to the rip track facility daily. The basis of this analysis is to achieve this without causing problems for KCSI management.

In addition to analyzing the current system, three cases were tested.

Current system: Two servers, one shift and fifteen car capacity

Case 1: Two servers, one shift and twenty-two car capacity

Case 2: One server, two shifts and fifteen car capacity

Case 3: One server, two shifts and twenty-two car capacity

Two simulation runs using the QSIM model were made using different random number seeds. Following are the aggregate results:

	ρ	L	L_q	W	W_q
Current System	62%	6 cars	4 cars	2 hours	1.5 hours
Case 1	63%	6 cars	4 cars	2 hours	1.5 hours
Case 2	63%	6 cars	5 cars	4 hours	3.5 hours
Case 3	63%	6 cars	5 cars	4 hours	3.5 hours

Table 3. QSIM Analysis Results

The simulation runs indicate that the server utilization rate is virtually the same in each case, to include the current system. Increasing the queue population to twenty-two cars has no adverse affect on service productivity. The system operating characteristics remain the same as in the current case (i.e. queue length and queue wait). Case one appears to be the optimal choice to be able to enhance the operational efficiency of ultimately the Knoche rail yard operations. There is no demand for more repairmen or for current repairmen to work longer hours. A summary of results are located in Appendix B.

Switching bad order cars directly to the rip track facility achieves several objectives.

1. The intermingling that occurs due to the layout and design of the yard can be minimized. Additional space becomes available within the yard, which allows more cars

to be placed on switch tracks designated by their respective destination.

2. The direct benefit is that congestion is minimized. Currently, a bad order car spends 40 to 54 hours from the time it is identified as needing repair to the time it is switched onto classification tracks for departure. It is highly probable that this time interval can be decreased as cars arrive to the rip track facility sooner. Spotting bad order cars directly to the rip track facility from the receiving yard would produce this result.

3. Finally, the amount of double handling by switch engines daily may be decreased by as much as 96 percent (see tables 1 and 2), which should be of economical interest to the KCSI management.

Research Difficulties

To analyze the rip track facility operation effectively, data should be collected over a twenty-four hour period. The limiting factor during this research was the lack of data. A major research difficulty was the inability of both KCSI and the researcher to capture data for a twenty-four hour operation.

In an attempt to collect data, two observations were noted. First, due to the rate at which bad order cars arrived at rip track seventeen, the researcher would need to spend approximately three continuous twenty-four hour periods at the Knoche rail yard, and second, unless bad order cars arrived at designated tracks (GI and rip track), there would be no way of knowing whether bad order cars arrived at other tracks. It may prove valuable for KCS to acquire a terminal performance measurement system, which

monitors the operation to provide data. It is hoped that this would result in corrective action to prevent deterioration in performance.

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[1] Robert A. Gantt. "A Study of Rail Congestion in the Kansas City Southern Railway System" (MMAS thesis, United States Army Command and General Staff College, Fort Leavenworth, Kansas, 1998), 43.

[2] P. J. Wong et al., *"Improved Railroad Operations Using a Railroad Automated Indentification and Location System*, vol. 1, *New Procedures for Making Tactical Operations Planning Decisions"* (Menlo Park, CA: SRI International, 1977), photocopied, 48.

[3] Mark Davidson, Chief, Strategic Plans Division, Kansas City Southern Railway, Kansas City, Missouri, interview by author, Kansas City Southern Railway Headquarters, Kansas City, Missouri, 1 September 1998.

[4] Dennis Lincoln, Car Foreman, Kansas City Southern Railway, Kansas City, Missouri, interview by author, Knoche Rail Yard, Kansas City, Kansas, 2 April 1999.

[5] Dennis Lincoln, Car Foreman, Kansas City Southern Railway, Kansas City, Missouri, interview by author, Knoche Rail Yard, Kansas City, Kansas, 29 December 1998.

[6] Bob Lape, Interview by author, 12 October 1998, Kansas City, Kansas, Knoche Rail Yard, Kansas City, Kansas.

[7] Bill Wolfe, Yard Master, Kansas City Southern Railway, Kansas City, Missouri, interview by author, Knoche Rail Yard, Kansas City, Kansas, 20 November 1998.

[8] Dennis Lincoln, Car Foreman, Kansas City Southern Railway, Kansas City, Missouri, interview by author, ,Knoche Rail Yard, Kansas City, Kansas, 29 December 1998.

[9] Ibid,.

[10] Ibid, 2 April 1999.

[11] Tim Lincoln, Mechanical Officer, Kansas City Southern Railway, Kansas City, Missouri, interview by author, Knoche Rail Yard, Kansas City, Kansas, 29 December 1998.

[12] Ibid,l

[13] Barry Crilley, Yard Master, Kansas City Southern Railway, Kansas City, Missouri, interview by author, Knoche Rail Yard, Kansas City, Kansas, 29 April 1999.

[14] Ibid,.

[15] Joseph M. Sussman, "The Relation of Terminal Performance to Level of Service in the Freight Industry" (speech presented at the seminar on Tactical Performance Measurement Systems, Chicago, 21-22 May 1975), Department of Transportation, Washington, D.C.

[16] Richard Taylor, Assistant Trainmaster, Kansas City Southern Railway, Kansas City, Missouri, interview by author, Knoche Rail Yard, Kansas City, Kansas, 12 March 1999.

[17] Rick Mygatt, Mechanical Supervisor, Kansas City Southern Railway, Kansas City, Missouri, interview by author, Knoche Rail Yard, Kansas City, Kansas, 5 March 1999.

[18] Rick Mygatt, Mechanical Supervisor, Kansas City Southern Railway, Kansas City, Missouri, interview by author, Knoche Rail Yard, Kansas City, Kansas, 5 March 1999.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this research project was to enhance the operational efficiency of the rip track facility. To conduct this research project, a primary question and four subordinate questions were addressed.

Summary of Findings

Through both an objective and subjective analysis of the rip track facility, we found that the operational efficiency of the rip track facility can be enhanced. The findings are as follows.

The most significant finding in this study is that by increasing the queue population from fifteen to twenty-two is feasible without causing problems for KCSI management. The QSIM simulation reveals that the change in repairmen utilization is not affected by an increase of car arrivals. Finally, this change can be implemented without repairmen working additional time or hiring additional repairmen. It is essentially a cost free policy change.

The second significant finding is the modification of the bad order car handling process. Currently, bad order cars are spotted to switch tracks prior to entering the rip track facility.[1] There is no safety factor that prohibits bad order cars from being spotted directly to the rip track facility. Therefore if cars are spotted directly to the rip track facility, this change in standard operating procedure can (1) reduce the use of switch engines by as much as 96 percent, (2) reduce the amount of time a bad order car sits idle prior to repair, (3) reduce intermingling, (4) minimize congestion within the yard, and (5) potentially reduce the number of "36-hour count" cars. There is no good way to model

savings and time but this policy change will save switch engine time. These changes can improve the operational efficiency of both the rip track facility and the Knoche rail yard.

Recommendations

The following recommendations are based on the analysis and conclusions drawn for this research project.

1. Spot bad order cars directly to the rip track facility.

2. Spot twenty-two cars daily to the rip track facility, or a number of cars that brings the daily total quantity to twenty-two.

3. Establish and implement standard operating procedures that provide guidance in managing rail yard operations.

4. Acquire a terminal performance measurement system to monitor the operations to provide data that result in corrective action to prevent deterioration in performance. A data collection instrument would prove valuable in producing the required data necessary to effectively model and analyze the entire Knoche rail yard system. It would be beneficial for KCSR to develop a tracking system that tags rail car times as they flow through each event within the Knoche rail yard. The functional requirements of such a system would portray the actual performance of the rail yard operation and enhance any future analysis.

A terminal performance measurement system should be acquired that has the capability to track arrival and departure times in and out of each event within the Knoche rail yard. Additionally, this system should be capable of monitoring the life cycle of each rail car that flows to and from the Knoche rail yard.

Suggestions for Further Research

Further research that may prove valuable to rail management includes several areas. Stanford Research Institute International, in conducting interviews of key decision makers, found that an absence of standard operating procedures resulted in inefficiency among railroad operations. The Knoche rail yard operations are conducted based on the experience or lack of experience of key decision makers, such as yard masters and the superintendent. KCS could likely benefit from an analysis of the effects of having standard operating procedures in conducting rail yard operations.

A second area involves yard design. This can have a substantial impact on the ability of a terminal to process rail cars. The layout of the rail yard can adversely affect service reliability and car utilization. This is true if problems experienced in the Knoche rail yard are due to a layout that does not accommodate its rail yard operations. Future research should focus on analyzing the upgrade and expansion of existing facilities based on traffic flow and unused real estate either part of or contiguous to the rail yard. Prior to this research, it may prove worthwhile to analyze the overall efficiency of the Knoche rail yard.

A third area involves modeling. In analyzing Knoche rail yard operations, either an objective or subjective approach can be taken. KCS could definitely benefit from a simulation that models their entire system and that would enable them to obtain specific system attributes (i.e. phase duration for an individual rail car). Two known simulation models may be used: Simulation Language Alternative Modeling or Simulation with Arena. Further analysis and modeling is predicated on more data collection.

Finally, it is assumed in queueing analysis, as well as in all other management science models, that certain parameters will be provided by the decision maker. For waiting-line analysis, it is assumed that management can provide reasonably accurate estimates of the values of C_I (cost per unit time of server idle time) and C_W (cost per unit time of customer waiting time). The actual process by which such managerial estimates are derived constitutes a field of study in itself and can be pursued further.

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[1] Barry Crilley, Yard Master, Kansas City Southern Railway, Kansas City, Missouri, interview by author, Knoche Rail Yard, Kansas City, Kansas, 29 April 1999.

APPENDIX A

DATA

This appendix contains the objective data obtained from KCSI by the researcher. These data reflect all cars requiring repair, independent of whether they entered the rip track facility. Rick Mygatt, General Car Foreman, indicates that 85 to 90 percent of the data represent bad order cars that enter the rip track facility. A 90 percent estimate is used in this analysis.

REPORT FOR THE MONTH OF SEPTEMBER 98
Cars Inspected at Kansas City

DATE	UNIT COAL TRAINS	UNIT GRAIN SODA ASH	TRANSFER CARS	TOTAL CARS INSPECTED	BAD ORDER CARS	NUMBER OF CARS REPAIRED	OUTBOUND TRAINS	OUTBOUND TRANSFERS
1	0	181	370	551	11	25	364	184
2	0	0	337	337	17	10	348	161
3	0	0	261	261	13	11	287	173
4	115	0	286	401	16	13	436	135
5	0	0	229	229	29	19	282	92
6	0	0	370	370	17	30	378	154
7	0	0	201	201	16	6	418	195
8	0	0	195	195	15	23	316	81
9	0	0	234	234	12	21	324	196
10	0	0	319	319	14	13	262	184
11	0	0	158	158	9	28	315	123
12	0	26	364	390	18	5	436	100
13	0	74	213	287	14	13	263	136
14	0	0	296	296	7	18	325	179
15	0	0	369	369	7	5	342	142
16	0	0	248	248	8	13	366	96
17	0	0	266	266	20	14	410	160
18	0	0	279	279	5	16	414	128
19	0	0	276	276	25	6	334	194
20	0	0	431	431	17	18	270	145
21	0	0	271	271	9	10	532	75
22	0	0	196	196	21	10	330	123
23	0	0	328	328	13	17	378	139
24	0	0	153	153	12	27	425	143
25	0	0	344	344	16	17	530	214
26	0	0	333	333	36	17	502	149
27	0	0	303	303	22	23	382	170
28	0	0	191	191	22	32	370	116
29	0	0	274	274	15	15	318	162
30	0	0	257	257	17	23	264	149
TOTALS	115	281	8362	8748	473	501	10975	4398
Avg Per Day	3.83	9.37	278.40	291.60	15.77	16.70	365.83	146.60

Percentage of total cars bad ordered is 5.41%

Percentage of cars bad ordered excluding coal trains is 5.48%

Note: Unit coal train count is for Hawthorne trains only.

REPORT FOR THE MONTH OF OCTOBER 98 Cars Inspected at Kansas City								
DATE	UNIT COAL TRAINS	UNIT GRAIN SODA ASH	TRANSFER CARS	TOTAL CARS INSPECTED	BAD ORDER CARS	NUMBER OF CARS REPAIRED	OUTBOUND TRAINS	OUTBOUND TRANSFERS
1	0	0	274	274	18	16	378	99
2	0	0	293	293	17	16	253	219
3	0	0	170	170	18	18	360	178
4	0	0	284	284	14	10	363	82
5	0	0	153	153	10	20	395	90
6	0	0	316	316	18	23	218	263
7	0	0	165	165	3	13	325	157
8	0	0	233	233	11	13	415	104
9	0	0	265	265	8	17	542	192
10	0	0	188	188	32	12	304	257
11	110	0	314	424	14	9	349	203
12	0	0	301	301	12	19	325	157
13	110	0	166	278	7	7	305	180
14	0	0	266	266	12	20	384	162
15	0	0	194	194	36	14	347	130
16	0	0	355	355	11	27	265	141
17	0	0	407	407	18	25	415	169
18	0	0	320	320	26	11	185	239
19	0	0	271	271	21	22	498	146
20	0	97	291	388	22	36	458	145
21	0	0	147	147	21	16	150	182
22	0	0	207	207	18	13	351	235
23	0	0	225	225	18	24	395	161
24	0	0	208	208	25	21	372	170
25	0	0	221	221	9	33	308	130
26	0	0	291	291	21	58	295	172
27	0	0	198	198	14	29	374	176
28	0	0	160	160	15	24	398	85
29	0	0	233	233	15	14	272	127
30	0	0	323	323	10	15	378	173
31	0	0	130	130	8	13	285	136
TOTALS	220	97	7571	7888	502	586	10672	5061
Avg Per Day	7.10	3.13	244.23	254.45	16.19	18.90	344.26	163.26

Percentage of total cars bad ordered is 6.36%

Percentage of cars bad ordered excluding coal trains is 6.55%

Note: Unit coal train count is for Hawthorne trains only.

REPORT FOR THE MONTH OF NOVEMBER 98 Cars Inspected at Kansas City								
DATE	UNIT COAL TRAINS	UNIT GRAIN SODA ASH	TRANSFER CARS	TOTAL CARS INSPECTED	BAD ORDER CARS	NUMBER OF CARS REPAIRED	OUTBOUND TRAINS	OUTBOUND TRANSFERS
1	0	0	281	281	7	12	517	153
2	0	0	236	236	10	17	319	205
3	0	0	196	196	13	17	422	105
4	0	0	232	232	5	10	281	132
5	0	0	242	242	20	9	295	156
6	0	0	225	225	15	16	283	184
7	0	0	234	234	8	9	413	152
8	0	0	190	190	47	34	359	141
9	0	0	306	306	11	21	221	102
10	0	0	201	201	6	14	378	168
11	0	0	142	142	6	18	368	204
12	0	0	105	105	4	8	234	81
13	0	10	193	203	12	17	394	164
14	0	0	242	242	12	12	361	185
15	0	0	266	266	27	10	366	191
16	0	0	139	139	8	15	250	8
17	0	0	111	111	6	7	444	130
18	0	0	307	307	16	16	302	150
19	0	0	160	160	6	12	320	162
20	0	0	257	257	3	14	175	137
21	0	72	251	323	19	9	540	86
22	0	0	307	307	3	11	340	159
23	0	0	127	127	12	13	315	0
24	0	0	191	191	13	12	451	233
25	115	0	317	432	14	11	379	201
26	0	0	388	388	24	6	432	0
27	0	0	209	209	16	7	445	174
28	115	0	154	269	9	16	445	169
29	0	0	297	297	19	17	324	93
30	0	0	227	227	9	15	328	224
TOTALS	230	82	6733	7045	380	405	10701	4258
Avg Per Day	7.67	2.73	224.43	234.83	12.67	13.50	356.70	141.93

Percentage of total cars bad ordered is 5.39%

Percentage of cars bad ordered excluding coal trains is 5.58%

Note: Unit coal train count is for Hawthorne trains only.

REPORT FOR THE MONTH OF DECEMBER 98
Cars Inspected at Kansas City

DATE	UNIT COAL TRAINS	UNIT GRAIN SODA ASH	TRANSFER CARS	TOTAL CARS INSPECTED	BAD ORDER CARS	NUMBER OF CARS REPAIRED	OUTBOUND TRAINS	OUTBOUND TRANSFERS
1	0	0	169	169	15	21	526	159
2	0	0	318	318	13	14	354	165
3	0	171	102	273	19	21	374	118
4	0	0	310	310	11	13	380	107
5	0	0	289	289	16	13	391	256
6	0	0	347	347	6	8	182	113
7	0	83	151	234	2	23	278	49
8	0	0	301	301	11	0	622	203
9	0	0	203	203	18	8	376	169
10	115	0	310	425	12	16	494	263
11	0	0	231	231	14	12	300	179
12	0	0	240	240	19	11	315	372
13	0	0	193	193	14	9	307	247
14	0	0	315	315	21	24	351	157
15	0	0	185	185	18	13	444	128
16	0	0	183	183	10	26	286	142
17	0	23	201	224	6	20	573	117
18	0	0	175	175	18	17	378	179
19	115	0	229	344	10	15	415	249
20	0	0	73	73	6	13	338	183
21	0	0	438	438	17	9	270	162
22	0	0	147	147	18	8	310	114
23	0	105	253	358	8	14	346	176
24	0	0	153	153	6	3	0	35
25	0	0	111	111	14	1	148	53
26	0	0	131	131	15	1	587	202
27	115	0	354	469	10	16	180	283
28	0	0	269	269	17	24	413	337
29	0	0	292	292	8	17	374	123
30	0	95	120	215	10	11	295	156
31	0	66	319	385	4	0	120	166
TOTALS	345	543	7112	8000	388	410	10736	5422
Avg Per Day	11.13	17.52	229.42	258.06	12.52	13.23	346.32	174.90

Percentage of total cars bad ordered is 4.85%

Percentage of cars bad ordered excluding coal trains is 5.07%

Note: Unit coal train count is for Hawthorne trains only

REPORT FOR THE MONTH OF JANUARY 99 Cars Inspected at Kansas City								
DATE	UNIT COAL TRAINS	UNIT GRAIN SODA ASH	TRANSFER CARS	TOTAL CARS INSPECTED	BAD ORDER CARS	NUMBER OF CARS REPAIRED	OUTBOUND TRAINS	OUTBOUND TRANSFERS
1	0	0	141	141	18	6	487	19
2	116	0	305	421	12	14	245	209
3	0	0	138	138	6	17	165	46
4	0	0	201	201	9	13	208	179
5	115	0	260	375	19	13	422	195
6	0	0	149	149	16	16	201	215
7	0	0	150	150	9	23	378	66
8	115	68	246	429	13	12	303	332
9	0	0	155	155	15	12	418	93
10	0	0	194	194	19	12	308	155
11	0	0	220	220	14	17	355	217
12	115	0	141	256	11	15	525	219
13	0	0	225	225	13	16	251	205
14	0	0	209	209	14	21	157	132
15	0	0	349	349	16	22	447	341
16	115	0	272	387	24	8	525	288
17	0	0	269	269	22	14	447	187
18	0	0	212	212	9	15	357	250
19	115	0	172	287	15	19	466	236
20	0	0	224	224	20	22	323	195
21	0	100	335	435	17	16	304	247
22	0	0	228	228	19	21	472	196
23	0	0	363	363	16	12	366	232
24	0	0	151	151	15	16	366	182
25	0	0	361	361	55	28	404	114
26	115	113	194	422	47	53	432	198
27	0	0	261	261	41	34	302	144
28	115	0	203	318	58	52	269	171
29	0	0	287	287	20	23	353	306
30	0	0	213	213	12	29	320	207
31	115	0	428	543	9	12	495	265
TOTALS	1036	281	7256	8573	605	605	11062	6043
Avg Per Day	33.42	9.06	234.06	276.55	19.52	19.52	356.84	194.94

Percentage of total cars bad ordered is 7.06%

Percentage of cars bad ordered excluding coal trains is 8.03%

Note: Unit coal train count is for Hawthorne trains only.

REPORT FOR THE MONTH OF FEBRUARY 99
Cars Inspected at Kansas City

DATE	UNIT COAL TRAINS	UNIT GRAIN SODA ASH	TRANSFER CARS	TOTAL CARS INSPECTED	BAD ORDER CARS	NUMBER OF CARS REPAIRED	OUTBOUND TRAINS	OUTBOUND TRANSFERS
1	0	0	194	194	13	21	248	110
2	0	104	234	338	13	25	403	122
3	0	0	374	374	22	12	289	104
4	115	0	214	329	16	20	504	258
5	0	0	239	239	18	27	425	197
6	115	0	202	317	21	8	285	233
7	0	0	213	213	13	11	464	182
8	117	0	423	540	19	18	401	156
9	0	0	335	335	16	10	295	184
10	115	0	167	282	25	12	473	122
11	0	0	328	328	10	23	257	161
12	117	0	264	381	19	25	432	178
13	0	0	288	285	18	11	343	216
14	0	0	226	226	7	13	308	325
15	115	0	207	322	27	7	398	194
16	0	0	174	174	15	20	286	267
17	0	0	209	209	16	20	353	267
18	0	0	154	154	11	13	297	218
19	0	0	239	239	8	18	505	136
20	0	0	184	184	8	14	353	134
21	0	0	175	175	10	12	311	168
22	0	0	241	241	8	15	321	189
23	0	0	269	269	10	11	282	146
24	0	0	374	374	21	22	374	248
25	0	0	355	355	13	20	517	158
26	0	0	310	310	17	12	502	152
27	0	0	212	212	11	11	303	88
28	0	0	291	291	15	33	580	227
TOTALS	694	104	7095	7893	420	464	10590	5150
Avg Per Day	24.79	3.71	253.39	281.89	15.00	16.57	378.21	183.93

Percentage of total cars bad ordered is 5.32%

Percentage of cars bad ordered excluding coal trains is 5.83%

Note: Unit coal train count is for Hawthorne trains only.

APPENDIX B

ANALYSIS

This appendix reports the results of the QSIM simulation applied in analyzing the operating characteristics of the rip track facility. The unit of time used is days. Two simulation runs using the QSIM model were made using different random number seeds (-30,000 and 20,000) over a period of one thousand days. The following attributes were used:

1. Batch car arrivals
2. The max queue length used is seven and eleven.
3. The mean car arrival is 15.29 and the standard deviation is 8.38, which was calculated from the data contained in Appendix A.

Data results were similar for the two server cases and the one server cases, respectively.

Summary Results for Servers in Current

Servers	Util.	Wq.	Var.(Wq)	W.	Var.(W)	Obsvtn.
1	0.6308	0.2590	0.0431	0.3435	0.0500	7463
2	0.6258	0.2521	0.0401	0.3355	0.0478	7499

Data collection period: 0 to 1000.058 (in day)

Summary Results for Queues in Current

Queues	Qmax.	Qmin.	Current Q	Lq.	Var.(Lq)	L.
1	7	0	6	1.9204	5.5603	2.5512
2	7	0	7	1.9024	5.6422	2.5283

Data collection period: 0 to 1000.058 (in day)

Combined Results for Current

Util.= 1.25664	Lq. =3.8228	V.(Lq)= 11.20	L. =5.0795
Wq. = 0.2555	V.(Wq)=0.0416	W. =0.3395	V.(W) =0.0489

Data collection period: 0 to 1000.058 (in day)

Input Data of The Problem Current

Svr # 1 Mean time: 0.0830 Dstn: Expon	Svr # 2 Mean time: 0.0830 Dstn: Expon
Qu. # 1 Qu. limit: 7 Dspch: FIFO	Qu. # 2 Qu. limit: 7 Dspch: FIFO

Mean interarrival time = 1.0000 Dstn: Const Batch = 15.29 Random seed = 30000

Summary Results for Servers in Current						
Servers	Util.	Wq.	Var.(Wq)	W.	Var.(W)	Obsvtn.
1	0.6217	0.2548	0.0424	0.3391	0.0490	7379
2	0.6195	0.2530	0.0410	0.3346	0.0479	7588

Data collection period: 0 to 1000.014 (in day)

Summary Results for Queues in Current						
Queues	Qmax.	Qmin.	Current Q	Lq.	Var.(Lq)	L.
1	7	0	6	1.9325	5.6869	2.5542
2	7	0	7	1.8674	5.5063	2.4869

Data collection period: 0 to 1000.014 (in day)

Combined Results for Current			
Util.= 1.24117	Lq. =3.8000	V.(Lq)= 11.19	L. =5.0411
Wq. = 0.2539	V.(Wq)=0.0417	W. =0.3368	V.(W) =0.0485

Data collection period: 0 to 1000.014 (in day)

Input Data of The Problem Current	
Svr # 1 Mean time: 0.0830 Dstn: Expon	Svr # 2 Mean time: 0.0830 Dstn: Expon
Qu. # 1 Qu. limit: 7 Dspch: FIFO	Qu. # 2 Qu. limit: 7 Dspch: FIFO

Mean interarrival time = 1.0000 Dstn: Const Batch = 15.29 Random seed = 20000

Summary Results for Servers in Case1

Servers	Util.	Wq.	Var.(Wq)	W.	Var.(W)	Obsvtn.
1	0.6361	0.2593	0.0438	0.3435	0.0509	7555
2	0.6339	0.2570	0.0432	0.3423	0.0514	7430

Data collection period: 0 to 1000.15 (in day)

Summary Results for Queues in Case1

Queues	Qmax.	Qmin.	Current Q	Lq.	Var.(Lq)	L.
1	10	0	6	1.9048	5.5845	2.5409
2	10	0	7	1.9632	5.7164	2.5971

Data collection period: 0 to 1000.15 (in day)

Combined Results for Case1

Util.= 1.26998	Lq. =3.8680	V.(Lq)= 11.30	L. =5.1380
Wq. = 0.2582	V.(Wq)=0.0435	W. =0.3429	V.(W) =0.0511

Data collection period: 0 to 1000.15 (in day)

Input Data of The Problem Case1

Svr # 1 Mean time: 0.0830 Dstn: Expon	Svr # 2 Mean time: 0.0830 Dstn: Expon
Qu. # 1 Qu. limit: 11 Dspch: FIFO	Qu. # 2 Qu. limit: 11 Dspch: FIFO

Mean interarrival time = 1.0000 Dstn: Const Batch = 15.29 Random seed = 30000

Summary Results for Servers in Case1						
Servers	Util.	Wq.	Var.(Wq)	W.	Var.(W)	Obsvtn.
1	0.6231	0.2589	0.0439	0.3414	0.0501	7551
2	0.6183	0.2551	0.0408	0.3383	0.0471	7434

Data collection period: 0 to 1000.003 (in day)

Summary Results for Queues in Case1						
Queues	Qmax.	Qmin.	Current Q	Lq.	Var.(Lq)	L.
1	10	0	6	1.9471	5.7636	2.5702
2	10	0	7	1.9043	5.6068	2.5226

Data collection period: 0 to 1000.003 (in day)

Combined Results for Case1			
Util.= 1.24143	Lq. =3.8514	V.(Lq)= 11.37	L. =5.0928
Wq. = 0.2570	V.(Wq)=0.0423	W. =0.3399	V.(W) =0.0486

Data collection period: 0 to 1000.003 (in day)

Input Data of The Problem Case1	
Svr # 1 Mean time: 0.0830 Dstn: Expon	Svr # 2 Mean time: 0.0830 Dstn: Expon
Qu. # 1 Qu. limit: 11 Dspch: FIFO	Qu. # 2 Qu. limit: 11 Dspch: FIFO

Mean interarrival time = 1.0000 Dstn: Const Batch = 15.29 Random seed = 20000

Summary Results for Servers in Case2						
Servers	Util.	Wq.	Var.(Wq)	W.	Var.(W)	Obsvtn.
1	0.6295	0.2955	0.0451	0.3376	0.0468	14957

Data collection period: 0 to 1000.011 (in day)

Summary Results for Queues in Case2						
Queues	Qmax.	Qmin.	Current Q	Lq.	Var.(Lq)	L.
1	14	0	14	4.4204	23.25	5.0498

Data collection period: 0 to 1000.011 (in day)

Combined Results for Case2			
Util.= 0.62950	Lq. =4.4204	V.(Lq)= 23.25	L. =5.0498
Wq. = 0.2955	V.(Wq)=0.0451	W. =0.3376	V.(W) =0.0468

Data collection period: 0 to 1000.011 (in day)

Input Data of The Problem Case2
Svr # 1 Mean time: 0.0417 Dstn: Expon
Qu. # 1 Qu. limit: 14 Dspch: FIFO

Mean interarrival time = 1.0000 Dstn: Const Batch = 15.29 Random seed = 30000

Summary Results for Servers in Case2						
Servers	Util.	Wq.	Var.(Wq)	W.	Var.(W)	Obsvtn.
1	0.6226	0.2911	0.0444	0.3327	0.0463	14944

Data collection period: 0 to 1000.038 (in day)

Summary Results for Queues in Case2						
Queues	Qmax.	Qmin.	Current Q	Lq.	Var.(Lq)	L.
1	14	0	14	4.3495	23.13	4.9721

Data collection period: 0 to 1000.038 (in day)

Combined Results for Case2			
Util.= 0.62256	Lq. =4.3495	V.(Lq)= 23.13	L. =4.9721
Wq. = 0.2911	V.(Wq)=0.0444	W. =0.3327	V.(W) =0.0463

Data collection period: 0 to 1000.038 (in day)

Input Data of The Problem Case2
Svr # 1 Mean time: 0.0417 Dstn: Expon
Qu. # 1 Qu. limit: 14 Dspch: FIFO

Mean interarrival time = 1.0000 Dstn: Const Batch = 15.29 Random seed = 20000

Summary Results for Servers in Case3						
Servers	Util.	Wq.	Var.(Wq)	W.	Var.(W)	Obsvtn.
1	0.6373	0.2968	0.0470	0.3393	0.0490	14985

Data collection period: 0 to 1000.076 (in day)

Summary Results for Queues in Case3						
Queues	Qmax.	Qmin.	Current Q	Lq.	Var.(Lq)	L.
1	20	0	14	4.4471	23.21	5.0844

Data collection period: 0 to 1000.076 (in day)

Combined Results for Case3			
Util.= 0.63732	Lq. =4.4471	V.(Lq)= 23.21	L. =5.0844
Wq. = 0.2968	V.(Wq)=0.0470	W. =0.3393	V.(W) =0.0490

Data collection period: 0 to 1000.076 (in day)

Input Data of The Problem Case3
Svr # 1 Mean time: 0.0417 Dstn: Expon
Qu. # 1 Qu. limit: 22 Dspch: FIFO

Mean interarrival time = 1.0000 Dstn: Const Batch = 15.29 Random seed = 30000

Summary Results for Servers in Case3

Servers	Util.	Wq.	Var.(Wq)	W.	Var.(W)	Obsvtn.
1	0.6240	0.2961	0.0453	0.3378	0.0468	14985

Data collection period: 0 to 1000.002 (in day)

Summary Results for Queues in Case3

Queues	Qmax.	Qmin.	Current Q	Lq.	Var.(Lq)	L.
1	18	0	14	4.4375	23.65	5.0615

Data collection period: 0 to 1000.002 (in day)

Combined Results for Case3

Util.= 0.62399	Lq. =4.4375	V.(Lq)= 23.65	L. =5.0615
Wq. = 0.2961	V.(Wq)=0.0453	W. =0.3378	V.(W) =0.0468

Data collection period: 0 to 1000.002 (in day)

Input Data of The Problem Case3

|Svr # 1 Mean time: 0.0417 Dstn: Expon|

|Qu. # 1 Qu. limit: 22 Dspch: FIFO |

```
Mean interarrival time = 1.0000 Dstn: Const  Batch =  15.29  Random
seed = 20000
```

APPENDIX C

RAILROAD TRIP PLAN

This appendix includes an example of KCS' railroad trip plan for various routes. For KCS, a railroad trip plan defines the route that a train may take beginning at the Knoche rail yard. Within the new yard, KCS has designated specific switch tracks by destination of rail cars. The objective is to block an entire track without having to juggle rail cars to make a train. KCS is not always able to attain this objective due to intermingling of rail cars on a switch track bound for a different route.

Blocking from HEAD end to REAR end

	SET	DEPART
IMRL #112	**0300**	**0500**

160 River Jct manifest, 150 Chicago manifest, 150 TOFC, 170 TOFC, 130 TOFC

KCSH1 #5	**0500**	**0700**

32 Pittsburg, 40 Watts / Sallisaw, 46 Heavner, 54 Dequeen, 56 Ashdown, 58 Texarkana

KCSH7 #81	**1159**	**1400**

303 Artesia / 304 Meridian / 305 Jackson mix together (sets out at Jackson, 302 Vicksburg, 301 Monroe, 300 East Local (Bossier), 68 Texas to turn at the wye, 60 Shreveport

IMRL #264	**1400**	**1600**

100 Shorts, 120 Muscatine, 155 BRC, 130 & 140 mixed Nahant, 164 Mason City, 170 St. Paul, 180 Glenwood / West

KCBM #41	**1500**	**1700**

75 Tex Mex & TOFC, 70 Lake Charles, 72 Leesville, 74 Beaumont, 76 Port Author & TOFC

KCSL #373	**2000**	**2130**

Manifest, ConRail TOFC, Venice TOFC

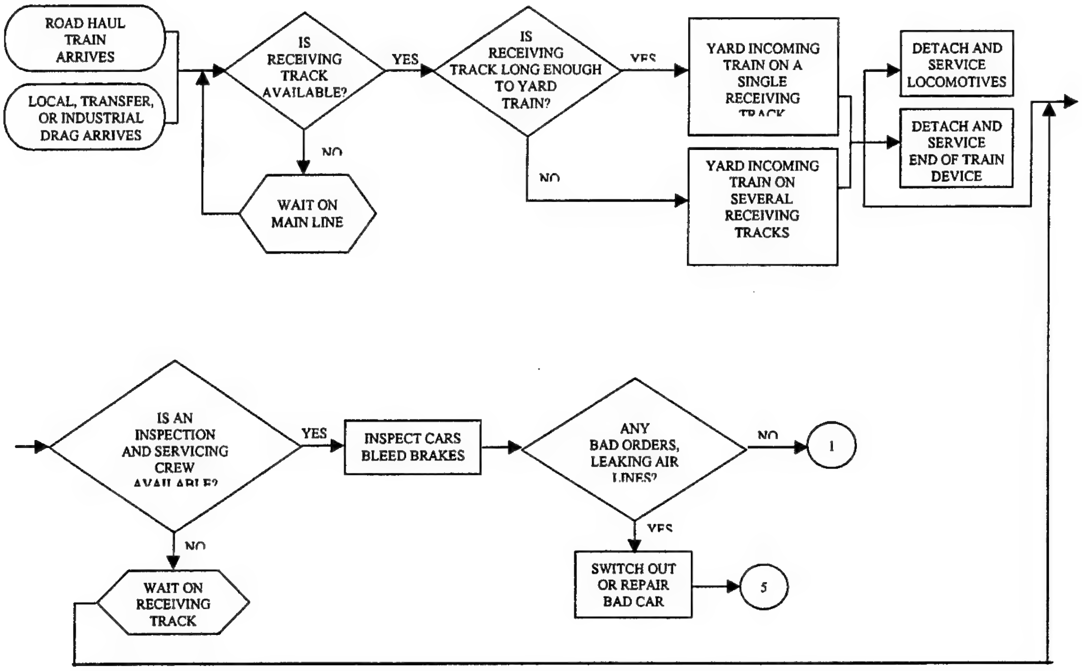
KCND #11	**2230**	**0005**

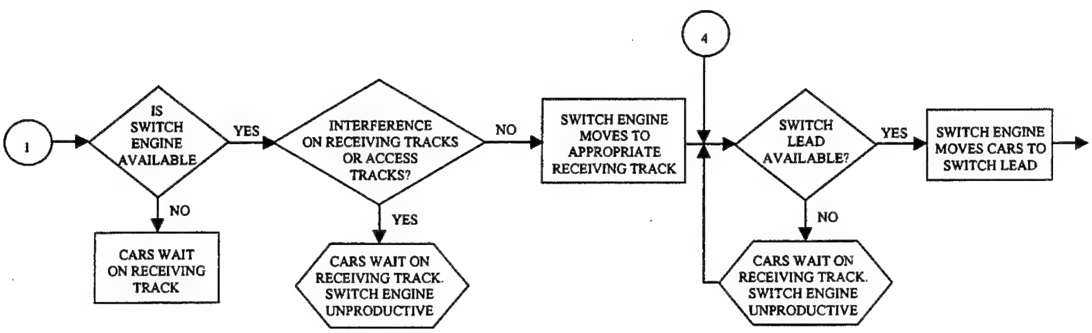
Mid So TOFC, Shreveport TOFC, New Orleans TOFC, 84 New Orleans manifest, 78 Baton Rouge manifest, Sallisaw TOFC, Dallas TOFC

APPENDIX D

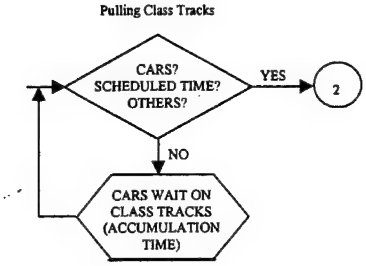
RAIL CAR HANDLING PROCESSES IN CLASSIFICATION YARDS

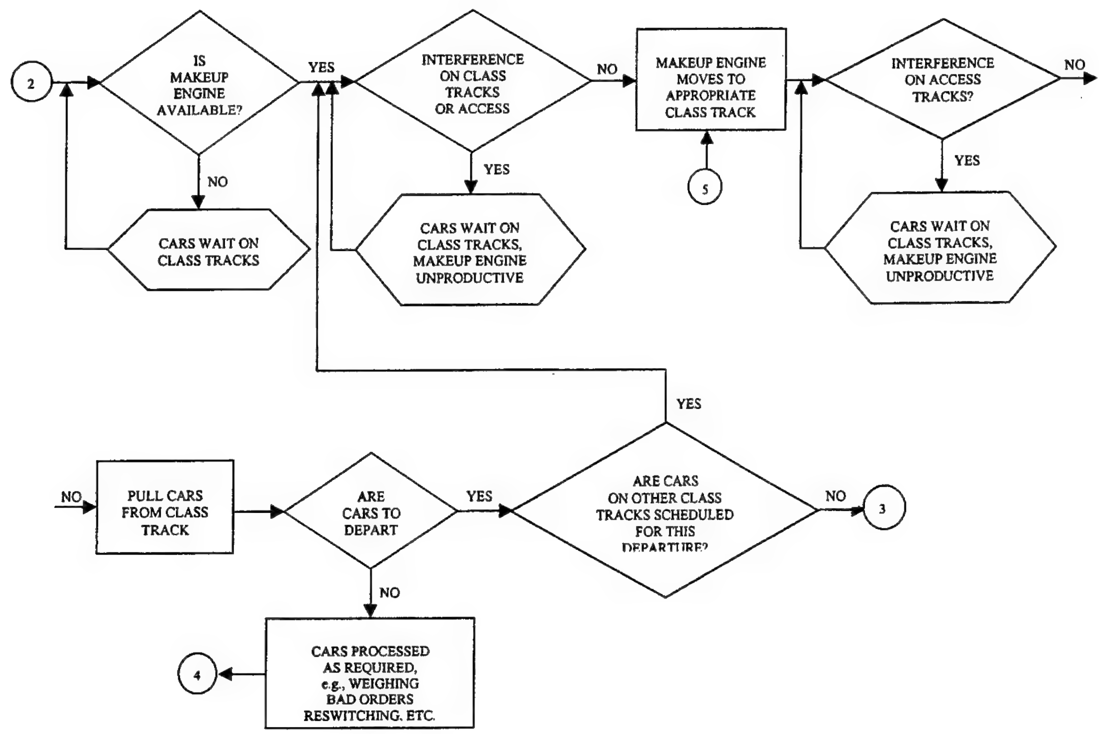
This appendix includes a flow chart that provides a detailed depiction of how rail cars flow through the Knoche rail yard.

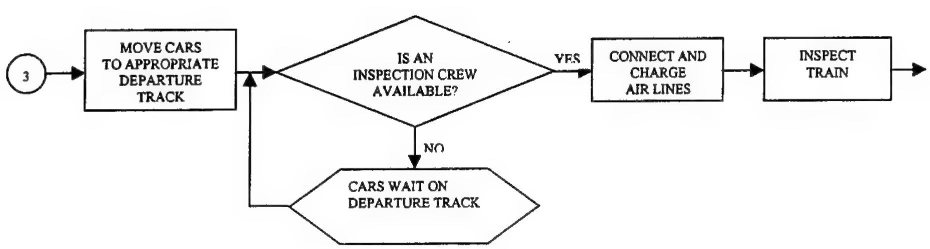


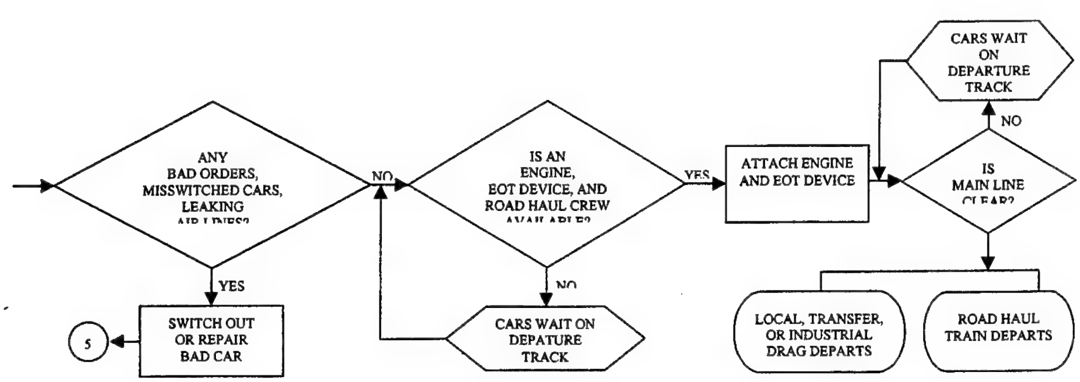


Decision Rule For Pulling Class Tracks




2
IS MAKEUP ENGINE AVAILABLE?
YES
NO
CARS WAIT ON CLASS TRACKS
INTERFERENCE ON CLASS TRACKS OR ACCESS
NO
YES
CARS WAIT ON CLASS TRACKS, MAKEUP ENGINE UNPRODUCTIVE
MAKEUP ENGINE MOVES TO APPROPRIATE CLASS TRACK
5
INTERFERENCE ON ACCESS TRACKS?
NO
YES
CARS WAIT ON CLASS TRACKS, MAKEUP ENGINE UNPRODUCTIVE
YES
NO
PULL CARS FROM CLASS TRACK
ARE CARS TO DEPART
YES
ARE CARS ON OTHER CLASS TRACKS SCHEDULED FOR THIS
NO
3
NO
CARS PROCESSED AS REQUIRED, e.g., WEIGHING BAD ORDERS RESWITCHING, ETC.
4

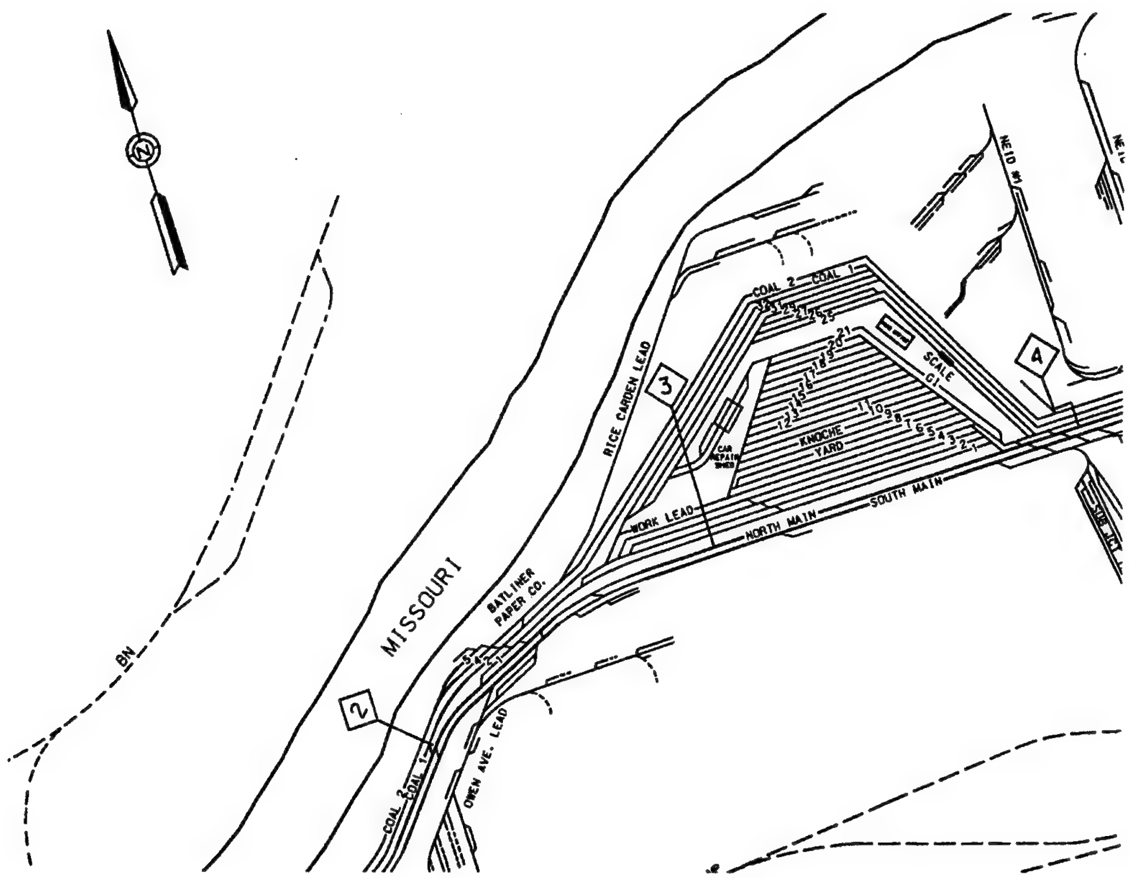

3
MOVE CARS TO APPROPRIATE DEPARTURE TRACK
IS AN INSPECTION CREW AVAILABLE?
YES
CONNECT AND CHARGE AIR LINES
INSPECT TRAIN
NO
CARS WAIT ON DEPARTURE TRACK


ANY BAD ORDERS, MISSWITCHED CARS, LEAKING
NO
IS AN ENGINE, EOT DEVICE, AND ROAD HAUL CREW
YES
ATTACH ENGINE AND EOT DEVICE
CARS WAIT ON DEPARTURE TRACK
NO
IS MAIN LINE
YES
SWITCH OUT OR REPAIR BAD CAR
5
NO
CARS WAIT ON DEPATURE TRACK
LOCAL, TRANSFER, OR INDUSTRIAL DRAG DEPARTS
ROAD HAUL TRAIN DEPARTS

APPENDIX E

KANSAS CITY SOUTHERN RAILWAY
KNOCHE RAIL YARD

The enclosed map shows Kansas City Southern tracks at the Knoche rail yard.



GLOSSARY

Bad Order. A freight car identified as in need of repair and placed out of service until repairs are made.

Block. An arrangement of railcars grouped by destination.

Car Foreman. A management personnel responsible to instruct car inspectors and repairmen.

Class I Railroad. A classification of regulated railroad companies having annual operating revenues of at least $50 million.

Classification. The process of grouping cars to make up a train according to destination.

Congestion. An excess buildup of freight cars at a particular place and time leading to friction and difficulties in moving freight cars throughout the rail network in a timely manner; too many freight cars for the amount of track space; inability to handle volume expeditiously as governed by the customer's demand or expectations exceeding the dwell time; a condition when inbound traffic overruns capacity to efficiently switch, classify, and push outbound traffic. Congestion is measured by the changes in "36-hour cars," and is quantified, as it relates to the Knoche Yard, as the point at which “36-hour cars” exceed 120 hours.

Crews. Established groups of rail and locomotive personnel teams to perform specific functions such as: switching cars, hauling interchange cars and making runs. Different types include train crews, engineering crews and yard crews.

Dwell Time. The length of time a freight car remains in a rail yard. This is measured from the time a car arrives in a yard until the time it departs the yard as part of a train or an interchange cut.

Flat Yard. A rail yard that uses switching engines to move individual cars from receiving tracks onto classification tracks.

Folding. Placing a block of railcars into a train. Assembling a train in preparation for departure.

General Car Foreman. A management personnel that oversees the functions of the repair/car department and manages car men.

Háulage Rights. An agreement between rail carriers allowing a carrier (Carrier A) to operate its train or another carrier's tracks (Carrier B) with the requirement that the other carrier's crews (from Carrier B) operate its train (Carrier A).

Hump Yard. A rail yard designed such that complete trains are pushed slowly up a raised portion of track--called a "hump"--where, at the crest, individual cars are uncoupled and allowed to coast to the desired classification tracks.

Inbound Train. Arriving manifest trains that will be received and whose cars will be broken down and reclassified according to destination.

Interchange Cut. Train or railcars designated to be delivered to or received from another rail company.

Interchange Partner. A number of rail companies that utilize their own and another company's rail line to deliver cargo to customers.

Intermodal Transport. The movement of freight over different modes of transportation.

Intermodal. Trailer that has been placed on a flat rail car.

Jeopardy Car. A rail car that is behind schedule.

Lead. Junction of track that gives access to a facility or another track.

Piggy-Back. An intermodal rail car carrying containers and/or trailers. Each intermodal car can be of differing lengths carrying multiple containers and/or trailers.

Power. A railroad locomotive.

Rail Car. A segment or link of a train.

Rail Yard. Synonymous with switchyard, terminal, and yard. Fundamentally comprised of receiving tracks, classification tracks and departure tracks. Normally contains an intermodal area.

Rip Track Facility. A maintenance facility for repair or upgrade of rail cars.

Round House. A locomotive inspection and maintenance facility characterized by its rotating "turntable" track.

Spot. The positioning of a rail car for an activity or event to occur.

Switch. A manual instrument used to direct rail cars onto a specific track during switching.

Switching. The transfer of cars between tracks.

Throughput. A measure of output in terms of railcars moving through a specific rail yard in a specified time period.

Trackage Rights. An agreement between rail carriers allowing a carrier to operate its train and crew on another carrier's tracks.

Track Space. The relative length of tracks available for movement or positioning of locomotives or freight cars.

Train Master. An individual responsible for supervising terminals at outlying points; ensures trains depart and operating rules are followed; and deals with customer complaints.

Unit Train. An entire train moving uninterrupted between origin and destination. Usually applies to trains of a single commodity such as coal or grain.

Yard Master. An individual that manages train makeup, ensures trains depart in a timely manner and controls all movement in and out of a rail yard.

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